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Minor Project
on
“iSnake - Multiplayer Intelligent Snake Game”

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by

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1 Acknowledgment

We would like to thank all those forum members at JavaGaming.org [http://www.javagaming.org] and Sun Java Forum [http://forum.java.sun.com] who replied to our endless queries without any complain. We offer gratitude to our teachers for guiding us throughout the project.

We acknowledge the creators of Quantum Random Bit Generator Service [QRBG – http://random.irb.hr], which provides our game server with high quality random numbers.
2 Abstract

This project aims to bring the fun and simplicity of snake game with some new features. It will include computer controlled intelligent opponents whose aim will be to challenge the human players. It will also have the multiplayer feature that will allow more than one players to play the game over a network.

This project explores a new dimension in the traditional snake game to make it more interesting and challenging. The simplicity of this game makes it an ideal candidate for a minor project as we can focus on advanced topics like multiplayer functionality and implementation of computer controlled intelligent opponents.
3 Objectives

This game aims to change the way people think of traditional snake game. It will offer the experience of commercial multilayer games to the player retaining the simplicity of traditional snake game.

The major objectives of this project are:

- Create a snake game that will have all the functionality of traditional snake games.
- Introduce multilayer functionality in the game that will allow several players to play a game simultaneously. It should be able to give the experience of a real time multiplayer game to the players.
- Introduce computer controlled intelligent opponent (unique feature of this game) to make the game more challenging and interesting. The movement and action of these intelligent opponents will be controlled by computer whose aim will be to eat the food before human players capture it.
4 Programming Environment

We used several open source tools to develop this project:

- **Netbeans 5.5 IDE**
  
  All the developers of iSnake team used Netbeans IDE for the development of this project.

- **Inkscape 0.45 and Gimp 2.2**
  
  These graphics development tools were extensively used for the development of User Interface components. The illustrations presented in this report have also been prepared using these open source tools.

- **Gnuplot**
  
  The data obtained during profiling of two path finding algorithms viz. Blackmamba and Viper was plotted using gnuplot.

- **OpenOffice Writer 2.2**
  
  All the project documents and this report were prepared using OpenOffice Writer 2.2.

- **Wireshark Network Traffic Analyzer 0.99.6**
  
  During the development of iSnake Game Server Manager (GSM) @ SF.net, Wireshark tool was used to analyze the network traffic.
5 Methodology

The complete iSnake application is divided into four major components:

- iSnake Client Application
- iSnake Game Server
- Intelligent Autonomous Opponent Snakes
- iSnake Game Server Manager (GSM) @ SF.net

5.1 iSnake Client Application

iSnake client application refers to the application used to play snake game. A player joins an already existing iSnake game server using this application.

![Block diagram of iSnake Client Application](Illustration 1: Block diagram of iSnake Client Application)

The main components of iSnake Client application are:

5.1.1 Client Encoder/Decoder

This module performs the encoding and decoding of messages leaving/arriving the client network interface module using the protocol standard described in ANNEX D: Inter Snake Communication Protocol.
5.1.2 Client Network Interface

It provides an interface to the Game Controller module for communication with the game server hosted at local/remote computer. It is responsible for triggering of appropriate methods of Game Controller when message from Game Server is received.

5.1.3 Input Handler

It manages the task of sampling key strokes from local player and forwarding it to Game Controller when requested. It maintains a queue of size 2 so that quick keystrokes are not lost. It is active only when the game is in running mode.

5.1.4 Game Field Matrix

Game Controller maintains the complete state of the game using game field matrix. It is a 2D array of size 58x58 (equal to the game field dimensions). Each game field object has a unique identifier in the game field. Game Controller updates the cells of this matrix in each cycle to register the changes that occur in the game.

5.1.5 Game Field Canvas

It represents the game field as seen by the player. Game Controller analyzes the game field matrix in each cycle and updates the game field canvas to represent the state of game in that game cycle. Double Buffering [using java.awt.Canvas.createBufferStrategy()] has been implemented to avoid flickering of game field. Each block in the game field has dimension 10x10 pixels.

The update of game field canvas occurs in the way similar to the refreshing technique of a cathode ray monitor. The game field matrix and game field canvas are updated in separate thread. The update of game field canvas starts by scanning each column of the 1st row in the game field matrix, then 2nd row and so on upto the 58th row. The game field is refreshed twice during each game cycle (two refresh cycle for game field canvas for each game cycle). This is done make the movements in the game field smoother.

5.1.6 User Interface Components

This module includes all the components, except game field, visible to the player.
The look and feel of default swing components have been overridden to give the feel of a game to the players. MIT OCW’s course¹ “[6.831] User Interface Design and Implementation” was very helpful during design of most of the user interface components of this game.

### 5.1.7 Game Controller

It is the most important component of the iSnake client application. It coordinates the working of all the other modules in the application and handles all the messages received from the game server. Game Controller maintains the game cycle when the game is running. This game cycle is synchronized with the game cycle of the game server. All the updates to game field matrix are done during this cycle time. After expiry of each game cycle the game field is repainted to reflect the changes in the game field.

### 5.2 iSnake Game Server

iSnake game server handles the multiplayer feature of this game and allows multiple iSnake client applications to play the game hosted by that particular game server.

![Illustration 2: Block diagram of iSnake Game Server](image)

The main components of iSnake Game Server are:

#### 5.2.1 Server Encoder/Decoder

This module performs the encoding and decoding of messages leaving/arriving the

¹ See References [Website]
server network interface module using the protocol standard described in *ANNEX D: Inter Snake Communication Protocol*.

### 5.2.2 Server Network Interface

It provides an interface to the Server Core module for communication with the remote/local players of the game being hosted. It is responsible for triggering of appropriate methods of Server Core when message from remote/local players is received.

### 5.2.3 Virtual Game Field

Game server maintains the state of the game using a 2D array of size 58x58 (similar to that used by Game Controller – refer to 5.1.4). The virtual game field is updated in every game cycle to reflect the changes in game field.

It is maintained by the game server to check whether the food has been eaten and whether any player has collide with the wall. It maintains the head coordinate (not the coordinates for tails) of each player. The head coordinate of players is moved in each game cycle and checked for the presence of wall/food in that coordinate position. Server Core generates corresponding event (collide or food eaten) and all the active players are informed about the event in the same cycle.

### 5.2.4 Player Information Manager

It manages the information about the players involved in the game. Player information like name, location, score, snake's starting position, snake color, etc are maintained. A new entry is added whenever a new player joins the game. Similarly, when the player leaves the game, it is removed.

### 5.2.5 Random Number Pool

Game server maintains a buffer of random numbers obtained from Quantum Random Bit Generator service [QRGB - http://random.irb.hr ]. This gives the game server access to true random number. These random data is used to generate the position of food and the starting coordinate of each player's snake.

If the random number service is unreachable pseudo random numbers are generated using java.util.Random class provided by Java.
5.2.6 Status Server

Status server maintains all the information required to reply the current status of the game server. The service of status server is utilized by iSnake Game Server Manager (iSnake - GSM)\(^2\) hosted at http://isnake.sf.net. The response of status server is a well formed XML document that is parsed by iSnake – GSM to display information about the game server in the website.

A typical response of Status Server is given below:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<iSnake>
  <GameServerData>
    <GameServerAddress>124.41.228.219</GameServerAddress>
    <GameServerPort>9669</GameServerPort>
    <NoOfPlayersOnline>5</GameServerLocation>
    <GameServerStatus>Waiting</GameServerStatus>
  </GameServerData>
</iSnake>
```

5.2.7 Server Core

It is the most important component of the iSnake Game Server. It coordinates the working of all the other modules in the application and handles all the messages received from the remote players.

When the game is in "Waiting" mode, Server Core provides the facility of chat messaging to the game players. During this state new players can join the game.

When all the players have sent signal to start the game, the Server Core changes state to “Running” mode. If a new player tries to join the game, it receives a “NAK” response. In this mode, Server Core maintains a game cycle time during which it receives the movement coordinates (in terms of deltaX and deltaY) from the players. If a player does not send any packet during this cycle time, server considers the movement coordinate sent in last cycle for the current game cycle. After expiry of cycle time, game server broadcasts a packet containing movement coordinates of each player to all the players.

---

\(^2\) Refer to “5.4 iSnake Game Server Manager (GSM) @ SF.net”
active in the game. The game server also checks if any player has eaten the food or if any players have collided to the wall in each cycle.

5.3 Intelligent Autonomous Opponent Snakes

These are computer controlled snakes, in the game, whose aim is to challenge the human players. We have two implementations of path finding algorithms to create intelligent autonomous opponent snakes. These algorithms return the shortest possible path from given source (S) and target (T) coordinate pair considering the obstacles (if any) present in the game field. The code name[^3] for these two implementations are:

- Blackmamba (refer to ANNEX - A)
- Viper (refer to ANNEX - B)

A detailed paper describing the algorithm used by these two implementation is present in ANNEX A and ANNEX B. To know which of the two implementations perform better, we profiled them using a simple JUnit test and the results were plotted using gnuplot:

[^3]: Named after two popular species of venomous snakes
**Turn around time plot**

The time elapsed between the instant of supplying the (source,target) coordinate pair (S,T) to the algorithm and the instant when it returns a path for supplied (S,T) pair is called turn around time. From the plot of illustration 3, it is clear that the turn around time for Viper is always smaller as compared to Blackmamba.

**Path Length plot**

The length of path (computed by counting the number of game field coordinates in the path) returned by the two path finding algorithms is depicted by the plot of illustration 4. It is clear from the plot that Viper implementation results in smaller paths (and hence efficient) as compared to Blackmamba implementation.

**NOTE**: The value of turn around time and path length for the coordinate pairs 5,7,8 have negative values for Blackmamba. This suggests that the algorithm was not able to compute a path for given (S,T) pair in given timeout period (250 ms for this test).
5.4 iSnake Game Server Manager (GSM) @ SF.net

iSnake Game Server Manager (iSnake – GSM) hosted at http://isnake.sf.net is used to manage all the information about iSnake game servers being hosted over the Internet.

![Block diagram of iSnake Game Server Manager at http://isnake.sf.net](image_url)

*Illustration 5: Block diagram of iSnake Game Server Manager at http://isnake.sf.net*

The iSnake – GSM has been developed using PHP. Java Web Start technology has been used to deploy iSnake application at our website which automatically downloads/install iSnake application and its library dependencies. This provides the gamers with the facility of “one click launch” of the iSnake application. It also make the distribution of updates of the iSnake application to the end users very convenient.

The iSnake application deployed at our website has been digitally signed by the iSnake team to address the security issues related to launch of Internet applications.
6 Project Management

The first thing we did before starting the work on iSnake was to register a project at Sourceforge\(^4\). Apart from hosting services, it provided us several code and project management services.

Illustration 6 shows the svn commit statistics for the isnake code repository at sourceforge. We collaborated on project documents (including prototype designs, project plan, TODO list, etc) using WIKI (http://isnake.wiki.sourceforge.net).

JUnit tests were developed to independently test some of the modules before integration. The integration of modules developed by the three developers was performed in three phases:

- Phase 1 Integration (Sep. 28, 2007) - chat functionality of the game was tested successfully

\(^4\) http://www.sourceforge.net
• Phase 2 Integration (Oct. 06, 2007) - successful testing of basic version of multiplayer snake game

• Phase 3 Integration (Feb 17 - 26, 2008) – integration of all the modules for iSnake 0.1 Beta release.

7 Documentation

Documentation of every task being done in the project was a priority for all the team members. Almost every portion of the source code contains full code documentation conforming to Javadoc standards.

```java
/**
 * Returns the object present in specified cell of game field
 * @param x x-coordinate of the specified cell
 * @param y y-coordinate of the specified cell
 * @return a Short value representing the object in cell specified by (x,y)
 */
public Short getGameFieldObject(int x, int y) {
    return fieldMatrix[x][y];
}
```

*Illustration 7: Screen shot of a snippet of source code showing method comments conforming to javadoc standards.*

There exists two path finding algorithms that implements intelligent opponent in the game viz-Blackmamba and Viper. These two algorithms have been fully documented with illustrations\(^5\).

The protocol devised for communication between game server and clients has been documented in *ANNEX-D*.

8 Limitations

The limitations of present implementation of iSnake are:

• The present implementation of iSnake can only be played in LAN. Due to large latency time and bandwidth limitation, it cannot be played over the Internet.

\(^5\) Refer to ANNEX – A,B
• Path finding algorithms (Blackmamba and Viper) implemented in this game have their own computation limitations which has been describe in ANNEX A,B.

• Full stress test of the application has not been done yet. Hence, the response of game server in unpredictable situations cannot be handled properly.

• iSnake's Game Server Manager (iSnake – GSM) located at http://isnake.sf.net is still in its early development phase. There are some unresolved security issues.

9 Future Enhancements

• Port iSnake to cell phone platform and One Laptop Per Child – OLPC (which uses Sugar Desktop environment). The presence of several connectivity options (Bluetooth, WIFI, GPRS, CDMA) in cell phones makes it a very attractive platform for a multiplayer game like iSnake. Local WIFI network formed by kids using OLPC laptops can be used as a platform for iSnake's deployment.

• As iSnake game server communicates with remote playing using a well defined and very simple protocol (Refer to ANNEX­ D), iSnake clients programmed in other programming platform like Flash, Python, etc can be developed.

10 Conclusion

We were successful in creating a multiplayer version of traditional snake game. The computer controlled intelligent opponents have been successfully tested in the game is a unique feature of iSnake.

We learned several project management techniques used by professionals to develop large scale project. The experience of working in team and integration of modules developed independently, with just requirement specifications, is a very important achievement for the iSnake team.
11 References

Books

1. *The Java Programming Language*, by Ken Arnold, James Gosling, David Holmes


   O'REILLY, May 2003, ISBN 81-7366-602-4

Websites

1. Netbeans Community Docs
   http://wiki.netbeans.org/wiki/view/CommunityDocs

2. The Inkscape Tutorials Blog
   http://inkscapetutorials.wordpress.com/

3. Smashing Magazine – On line magazine for designers
   http://www.smashingmagazine.com/

4. The Java Tutorials
   http://java.sun.com/docs/books/tutorial/

5. Timing Framework
https://timingframework.dev.java.net/

6. JavaGaming.org's Forum
   http://www.javagaming.org/forums/index.php

7. MIT Open Course Ware - 6.831 User Interface Design and Implementation

   http://theory.stanford.edu/~amitp/GameProgramming/

9. Arianne - a multiplayer online games framework
   http://arianne.sourceforge.net/

10. JavaDesktop Community Blog
    http://community.java.net/javadesktop/

11. Java Forum
    http://forum.java.sun.com

    http://www.curious-creature.org/

13. Filthy Rich Clients - Examples
    http://www.filthyrichclients.com/

14. A Distributed Multiplayer Game Server System

15. The Java Developers Almanac 1.4
    http://www.exampledepot.com/

16. Apache MINA Sample programs and tutorials
    http://mina.apache.org/
17. PHP Documentation for XML library

http://www.php.net/

18. Quantum Random Bit Generator Service (QRBG)

http://random.irb.hr/
ANNEX – A: Blackmamba – path finding algorithm

Proposed by: Abhishek Dutta

1 Some definitions and notations

1.1 Bounding Rectangle (br)

It is a rectangle in which the source and the target lie at two opposite corners of the rectangle. Source Bounding Rectangle (sbr0) and Target Bounding Rectangle (tbr0) represent the bounding rectangles from source and target – which are the same rectangle.

1.2 Partial Bounding Rectangle (pbr):

These rectangles touch either the source or the target node and not both. Two partial bounding rectangles touching 'S' and 'T' form paths from source to the target node.

Source Partial Bounding Rectangle (spbr)

The pbr touching the source node 'S'.

Target Partial Bounding Rectangle (tpbr)

The pbr touching the target node 'T'.

Refer to Illustration 8

1.3 Notations:

1.3.1 brNM

denotes a bounding rectangle that spans (or touches) N nodes along the x-axis and M nodes along the y-axis.
### 1.3.2 spbrNM

denotes a source partial bounding rectangle that spans (or touches) \( N \) nodes along the x-axis and \( M \) nodes along the y-axis.

### 1.3.3 tpbrNM

denotes a target partial bounding rectangle that spans (or touches) \( N \) nodes along the x-axis and \( M \) nodes along the y-axis.

### 1.3.4 hpNM

denotes a hopping point (coordinate specified with reference to source) along which spbrNM and tpbrNM are formed. This coordinate point is common to both spbrNM and tpbrNM.

### 1.3.5 Numbering of Paths

For any given bounding rectangle (br) there are only two possible paths as shown in Illustration 9. Path numbering convention applied is:

**Path1**: The x-coordinate of the path first changes followed by change in y-coordinate

**Path2**: The y-coordinate of the path first changes followed by change in x-coordinate

A source (S) and target (T) can be placed in four possible ways such that they lie on opposite ends of the diagonal. Considering the four positions \( (A,B,C,D) \) as depicted in Illustration 9, we have the following four cases:

#### 1.3.5.1 'S' placed at position A and 'T' placed at position C

\[ \text{Path1} = ABC, \text{Path2} = ADC \]

#### 1.3.5.2 'S' placed at position B and 'T' placed at position D

\[ \text{Path1} = BAD, \text{Path2} = BCD \]

#### 1.3.5.3 'S' placed at position C and 'T' placed at position A

\[ \text{Path1} = CDA, \text{Path2} = CBA \]
1.3.5.4 'S' placed at position D and 'T' placed at position B

Path1 = DCB, Path2 = DAB

2 Basis of this algorithm

In absence of any obstacles, the cost of moving from one node to another is constant throughout the game field. Hence, the shortest path is along the bounding rectangle edges if no obstacles are present in the path as shown in Illustration 9.

Both path1 and path2 have equal traveling cost provided that no obstacles are present along those paths. For any given br, if there exists a path from source to target inside the br then it will be the shortest path.

3 Paths generated by partial bounding rectangles

Four paths are generated by the source and target partial bounding rectangles for the given hopping point as shown in Illustration 10.
For any given (S,T) pair, we move the hopping point along the diagonal joining S and T.

Special considerations is required when:

- obstacles (wall) are present along the paths formed using the bounding and partial bounding rectangles.
- No possible path can be found using all the possible combinations of the partial bounding rectangles.
- the bounding rectangle is not a square (ie: for brNM, N ≠ M)

4 Description of the algorithm

Instead of considering all the possible cases at once, let us consider the working of algorithm in several stages (with increasing complications).

4.1 [A] Symmetric Bounding Rectangles (Simple Case)

For illustration purpose, let us first consider a game field of 6x6 nodes where source and target are placed at 'S' and 'T' respectively as shown in Figure A1. The following series of steps are executed to find a path from source to target. If obstacle is found in

Illustration 10: Four possible paths generated by source and target partial bounding rectangles (spbr,tpbr - depicted using red and green dotted lines respectively) for a given hopping point
all possible path of an stage the next stage is checked. The series of steps taken to obtain a path from 'S' to 'T' are:

4.1.1 Procedure of finding path for a given (S,T) pair

4.1.1.1 Figure A2 – initially the hopping point is hp66 (on the target). two paths formed along the bounding rectangle br66 (shown in red dotted rectangle in Figure A2) are checked for presence of obstacles. If no obstacles are found, either path1 or path2 are chosen (refer to Illustration 9). As both path1 and path2 have same path length, choice between these two paths is made based on some combination of sub paths and choosing the path whose length is shortest.

4.1.1.2 Figure A3 - four paths (refer to Illustration 10) formed along the source and target partial bounding rectangle (spbr55, tpbr22) are checked for presence of obstacle.

4.1.1.3 Figure A4 - four paths (refer to Illustration 10) formed along the source and target partial bounding rectangle (tpsbr44, ptbr33) are checked for presence of obstacle.

4.1.1.4 Figure A5 - four paths (refer to Illustration 10) formed along the source and target partial bounding rectangle (tpsbr33, ptbr44) are checked for presence of obstacle.

4.1.1.5 Figure A6 - four paths (refer to Illustration 10) formed along the source and target partial bounding rectangle (tpsbr22, ptbr55) are checked for presence of obstacle.

4.1.1.6 Figure A7 - This step is not necessary to execute as the task has already been performed in Step 1 using the bounding rectangle (br66).

See Illustration 11 for illustration of steps 1 to 6

Computation overhead calculations

Let the time required to check whether a partial bounding rectangle has an obstacle
time required to check whether a bounding rectangle has an obstacle = T2
for a game field NxN (row x col)
also let (to create the worst case)
the source 'S' be located at (1,1)
the target "T" be located at (N,N)
Total no. of possible hopping points (excluding the source) = N – 1
Hence, total time required to calculate a path\(^6\) = T2 + N * T1

---

\(^6\) See section “Requirements of this algorithm”
ANNEX - A

Illustration 11: Illustrations for “[A] Symmetric Bounding Rectangles (Simple Case)”

Fig. A1: Empty game field with source (snake) and target (food) placed at ‘S’ and ‘T’ respectively.

Fig. A2: [STEP1] The two paths of source partial bounding rectangle (spbr66, shown in red) is checked for presence of obstacles (wall).

Fig. A3: [STEP2] Four possible paths formed from the target partial bounding rectangle (tpbr22, shown in green) is checked along with spbr55 for presence of obstacle.

Fig. A4: [STEP3] Four possible paths formed from tpbr33 and spbr44 are checked for presence of obstacle.

Fig. A5: [STEP4] Four possible paths formed from tpbr44 and spbr33 are checked for presence of obstacle.

Fig. A6: [STEP5] Four possible paths formed from tpbr55 and spbr22 are checked for presence of obstacle.

Fig. A7: [STEP6] Two possible paths formed from tpbr66. This step is not required as it has already been checked in STEP1.
4.1.2 Backtracking

If 4.1.1.1 to 4.1.1.6 does not give a path from 'S' to 'T' the technique of backtracking will be applied. To illustrate the process of backtracking let us consider the scenario shown in Illustration 12.

The paths generated from the bounding rectangle (br44) and all the possible partial bounding rectangles contain obstacle. Hence the process discussed above will not result in any path from 'S0' to 'T'. For such scenario we can apply the process of backtracking.
Backtracking involves moving to the next outer (as inner bounding rectangles do not contain any path for sure) bounding rectangle a path to the target is found. Illustration 13 shows the result of backtracking. Backtracking from S0 to S1 (the next outer bounding rectangle) results in a bounding rectangle br55. This bounding rectangle does not also result in any path from S1 to T. Hence, next outer bounding rectangle is checked.

The next outer bounding rectangle (br66) is formed at node S1 as shown in
Illustration 14. This bounding rectangle has a path from S2 to T. Hence, the possible path is calculated to reach from S2 to T.

As we now have a path from S2 to T, we need to calculate a path from S0 to S2 so that we can ultimately reach T from S0. Now we calculate the possible path from S0 to S2 using the steps discussed above as shown in Illustration 15.

By joining the paths formed from the above two steps can be combined to form a path from S0 to T.

4.1.2.1 Determining next outer bounding rectangle during backtracking

Although the vertex for next outer bounding rectangle (required for backtracking) can be the next coordinate on the extended diagonal (as shown in Illustration 13,14), a simple technique can greatly reduce the number of backtracking steps of both source and target.

Let source (S) and target (T) be placed as shown in Illustration 16. A path from S to T contains two edges. Path1 contains edge1 and edge2. Path2 contains edge4 and edge3. While determining whether a path contains obstacle, the algorithm must also determine which edges contains obstacles (if any).
We can apply the following algorithm to determine the outer rectangles required during backtracking for source.

```java
if(edge1 contains obstacle) {
    if(edge4 contains obstacle) {
        source outer rectangle vertex = S'
    } else {
        source outer rectangle vertex = S'''
    }
} else {
    if(edge4 contains obstacle) {
        source outer rectangle vertex = S''
    } else {
        no backtracking required
    }
}
```

The outer rectangle for target, during backtracking, can be determined by applying similar logic for edge2 and edge3.

This technique works for different orientation of source and target as described in Section 1.3.5 Numbering of Paths.
4.1.2.2 Merging the paths formed while backtracking

While backtracking several sub paths are created while requires to be merged to form the final path from source to target. Let us consider a case as depicted in Illustration 17.

![Illustration 17: Sub paths formed during backtracking. Final path from S to T obtained by combining the sub paths.](image)

Due to the presence of wall (green blocks), S and T has to backtrack to S' and T' positions respectively. Here we obtain three sub paths which are:

- Path from S to S' : depicted by red colored line from S to S' (SubPath1)
- Path from S' to T : depicted by blue colored line from T to T' (SubPath2)
- Path from T' to T : depicted by pink colored line from T' to T (SubPath3)

We need to combine these three paths to obtain a final path from S to T (depicted by thick black line). If we add these three paths directly, the final path will contain overlapping paths (which is not required). The following algorithm can be applied to compute the final path (that does not contain any overlapping regions).

START

Step 1: Initialize FinalPath with the contents of SubPath1
FinalPath = SubPath1

Step 2: Now perform the following operations for each cell coordinate present in SubPath2 and SubPath2 (K=2,3)

    cellCoordinate = SubPathK.getCellCoordinate()
    
    if(FinalPath contains cellCoordinate)  {  
        remove cellCoordinate from FinalPath
    } else {

        add cellCoordinate to FinalPath
    }

Step 3: FinalPath contains discontinuities at the bends of path. Search for consecutive cell coordinate for which both x and y values of the coordinate change (ie: |dx| = 1, |dy| = 1).

Step 4: Correct these discontinuities by adding the missing cell coordinates.

END

4.2 [B] Asymmetric Bounding Rectangles

4.2.1 Simple Case

A problem arises when the bounding rectangle is asymmetric as shown in Illustration 18.

![Illustration 18: Case of asymmetric bounding rectangle (br63)](image)

The solution to this problem is to insert required number of dummy nodes between 'S' and 'T' so that the new bounding rectangle becomes symmetric as shown in
Illustration 19. The algorithm applied in “[A] Symmetric Bounding Rectangles (Simple Case)” can be now applied by considering the dummy nodes as normal game field nodes free from any obstacles.

4.2.2 S and T lying on same straight line (vertical or horizontal)

This case arises when both 'S' and 'T' lie on same straight line (horizontal or vertical) as shown in Illustration 20.

The case can be converted to “[A] Symmetric Bounding Rectangle (Simple Case)” case by adding dummy nodes as shown in Illustration 21.
5 Requirements

5.1 Constant time algorithm for obstacle detection

There must exist a constant time algorithm that can answer the question “Does the given bounding or partial bounding rectangle contain any obstacle?”. The constant time algorithm requirement means that the YES/NO decision of this algorithm should not depend on the size of rectangle under consideration or the number of obstacles present in the game field.

An important observation for iSnake game is that the obstacles in the game are not dynamic. In other words, the obstacles remain constant until a given FOOD is eaten by one of the players. Hence we can assume that the obstacle is constant during the execution of this path finding algorithm.

We apply the following algorithm to detect whether a given bounding rectangle contains any obstacles.

START
Step 1: Let \((x_1,y_1)\) = one corner of the bounding rectangle
\((x_2,y_2)\) = diagonally opposite corner of the bounding rectangle
obstacle = a set coordinates defining the obstacle (wall)

Step 2: Repeat step 2 for each cell coordinate in obstacle
\(oc = \) obstacle.getCellCoordinate()
path1HasObstacle = true, path2HasObstacle = true
if( \(x \geq x_1\) and \(x \leq x_2\) ) {
    if(!path1HasObstacle) {
        if( \(x_1.y_1.y\).equals(y) )
            path1HasObstacle = true
    }
    if(!path2HasObstacle) {
        if( \(x_2.y_2.y\).equals(y) )
            path2HasObstacle = true
    }
}
if ( \(y \geq y_1\) and \(y \leq y_2\) ) {
    if(!path1HasObstacle) {
        if( \(x_2.y_2.x\).equals(x) )
            path1HasObstacle = true
    }
    if(!path2HasObstacle) {
        if( \(x_1.y_1.x\).equals(x) )
            path2HasObstacle = true
    }
}
Step 3: if(path1HasObstacle) {
    if(path2HasObstacle)
        return NO PATH POSSIBLE
    else
        return PATH2 is OBSTACLE FREE
} else {


if(path2HasObstacle)
    return PATH1 is OBSTACLE FREE
else
    return PATH1 and PATH2 are OBSTACLE FREE

END

6 Limitations

6.1 This algorithm does not consider the transparent game field boundary (entry to one side of the field causes exit in the opposite side of the field as depicted in Illustration 22) during path calculation. Due to this limitation the computed path is not optimal.

Illustration 22: Transparent boundary of the game field

6.2 The hopping points are always taken from the diagonal line joining the source and target. Because of property of the algorithm, it is not able to compute paths when a complex structure of wall, as shown in Illustration 23, is present. This is the reason why Blackmamba implementation enters infinite recursion for such obstacles.
Illustration 23: Only 1 hopping point prevents this algorithm from computing path in presence of a complex structured wall
ANNEX – B: Viper – path finding algorithm

Proposed by: Suraj Sapkota

1 Assumptions

This algorithm assumes game field as follows:

- The rectangle with the dotted boarder is the **view port**(vp) of each player. Other rectangles attached with it in each side are the **virtual view port**(vvp) in their corresponding sides.
- Small yellow box is a **wall-unit**. Group of attached **wall-unit** is said to be **wall**.
- The border of the game-field are transparent unless there is wall.
- Wall is the only thing that a snake can strike to.

*Illustration 1: The game field (unfolded Envelop)*
- There can be multiple wall in the same game-field.
Finally considering all these, the aim of this algorithm is to find all (there may be multiple path of same distance) shortest path from the snake (head) to food. However as a result it will return only one among those paths.

2 Principal and implementation of this algorithm.

This algorithm will not deal with finding only one shortest path instead it calculates multiple path between the source and the destination, and all of these path have the same distance, the shortest distance. Actually the result is not in the form of multiple path, merely it is a collection of the points that it must pass through. It is the position of the points that make the path multiple. It is described later in more detail.

The algorithm follows following steps:

1. This algorithm begins with splitting all the game field into small rectangles (Fundamental open rectangle\(^7\) (FOR\(^8\))), say R1, R2, R3, ... Rn. If game-field (only view port), as a whole is said to be G. Then mathematically the wall, W can be defined as:

\[ W = G - R1 \cup R2 \cup R3 \cup ... \cup Rn \]

Broadly, this algorithm deals with splitting the game field into several (as many) rectangles such that, the union of all these small rectangles result in the game field that exclude wall. ie, the snake can move safely from any point in the rectangle(Ri) to any other point within the same rectangle(Ri)and hence called Open rectangles (OR).

---

\(^7\) Open rectangle is a rectangle that does not contain any wall. Within it snake can move freely.

\(^8\) The algorithm of generating FOR is discussed later.
2. Next we define Gate\(^9\) (Gate as in real life is a way to move from a FOR to another adjacent FOR) calculate the shortest distance between each two Gates of each FOR (eg: the shortest distance between the rectangles R1 and R5 are determined by the distance between the two gates of R3 shared with R1 and R5 respectively).

3. After the calculation of the shortest path, a graph as shown in Illustration 4 is formed.

In the above graph

i. The dotted lines defines direct connection, the **direct path**.

ii. The dark line shows a 1 step indirect connection between those rectangles that are not connected directly.

---

\(^9\) A gate must be common to only two FOR.
iii. \( S_{ij} \), beside with the vertex, (in graph) denotes that FOR\(-i\) is connected to FOR\(-j\) through this vertex and vice versa. This can also be called *indirect path*. And it posses the path distance.

iv. There may be multiple indirect path. Eg: We can move form 2 to 5 \((S_{25})\) in two different ways: via 3 or 5.

Some data that are associated with the rectangle (node in the graph) is shown below.

*Illustration 5: Data associated with each node*

4. Finally after all these calculation, we can calculate the path between two FOR's, the source and the destination with shortest distance. When two points (source and target) are given we can determine the FOR's, they lie in and can compute the path between them.

*Illustration 6: Path for a sample case.*

*Illustration 7: Zoomed view of "Illustration 6"*
The above sample case shown in illustration 6 and 7, shows the path calculated by the algorithm from the snake (red one pointed by an arrow A) to the food (blue one pointed by an arrow F). The points pointed by the arrows A, B, C, D, E and F are points (Hoping Points) that the intelligent player must pass through. And thus allowing multiple possibility for path.

The path is multiple because, there exist multiple way to go from A to B and E to F. Further the rectangles as formed by the points A and B (E and F) can also be called Derived open rectangle (as it doesn't contain any wall, and hence allows free movement of the snake inside it).

3 For dividing the Game field into fundamental open rectangle:

The algorithm involves slicing the game-field in cyclic-order in anti-clockwise direction starting with the left edge. As the game field initially has no terminating edge (as envelope) we start with (visually-) left-edge of the game field.

1. Initially starting from the Zeroth coordinate move to both sides until it strike to wall(-unit).Name it Fundamental Open Rectangle (FOR1 and FOR2 or Just R1 and R2). Illustration-8 and 9.

2. Now the game-field has shrunked to as shown in Illustration-10. (It now has changed to cylindrical shape from envelope shape.)

3. Moving in anti-clockwise direction, Slice from Illustration 9: Step 1 (b) bottom in both direction (up and down) to get other two rectangle R3 and R4. Illustration-11.
Till this step the rectangle was not bounded (either in all four sides (envelop) or in two sides (top and bottom) (cylinder)). From this step onward-the sliced game-field would be bounded.

4. Now try to slice rectangle from top left, bottom left, bottom right and top-right respectively. Here we fail to slice the rectangle from top-left and bottom-right as there is wall(-unit) at the edge.

We can now create two new rectangles from bottom-left and top-right namely R5 and R6. Illustration-13.


6. As earlier again try to slice the game-field in the anticlockwise direction starting from left. It will result in two more rectangle R7 and R8. Illustration-15.

During this we assume already sliced rectangle as a hollow space.

7. For Further Optimization we proceed by breaking down the rectangle that touches itself (eg: in this case, the top edged of rectangle R1 touch itself to its bottom edge). These type of rectangles are divided in the middle. This results in best utilization of the transparency of the Game Field.
4 Special case for Game Field with no wall

If there is no wall we simply chop the game field vertically and horizontally from the middle resulting in 4 FOR’s. This results in maximum utilization of the transparency of the game field. The result is shown in Illustration 17.
5 Salient Features:

- As most of the processing is done before the actual game starts, it must reduce the processing time during the game-time.
- The concept of open-rectangle allows multiple path, and hence within it the snake can be moved randomly towards the specified point. And hence it is intelligent.
- Furthermore, during the calculation of the path the snake can move within the FOR in which it currently lie.

6 Limitations:

- If the number of FOR increases to too high, then it will obviously be tough and slow to determine the shortest path.
ANNEX – C: Program flow

NOTE: "EXT" refers to the actions that are triggered by Client Network Interface module when messages are received from game server
Illustration 26: In STAGE-2 players can chat with each other. The game will start only when all the players connected to the game server send READY signal.

NOTE: "EXT" refers to the actions that are triggered by Client Network Interface module when messages are received from game server.
Illustration 27: STAGE-3 involves receiving different game data (like wall coordinates, food coordinate, snakes start position, etc)

NOTE: "EXT" refers to the actions that are triggered by Client Network Interface module when messages are received from game server
NOTE: "EXT" refers to the actions that are triggered by Client Network Interface module when messages are received from game server.

Illustration 28: STAGE-4 involves synchronization with the game server.
NOTE: "EXT" refers to the actions that are triggered by Client Network Interface module when messages are received from game server.

Illustration 29: STAGE-5 represents the state when game is being played.
ANNEX – D: Inter Snake Communication Protocol

The communication between the game server and client applications is done using the Inter Snake Communication Protocol (ISCP). The protocol contains five different classes. These are listed below:

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>Used for transmission of player's information (name, color, location). Used only when the player creates/joins the game.</td>
</tr>
<tr>
<td>ChatMessage</td>
<td>Transmits the chat message. Works only before the actual game starts.</td>
</tr>
<tr>
<td>ControlSignal</td>
<td>Transmits control signals between server and clients. These signals are mainly used for synchronization.</td>
</tr>
<tr>
<td>LevelData</td>
<td>Sends data required on level change (food, wall, score, life, etc). Sent initially when the actual game begins and then after every level change.</td>
</tr>
<tr>
<td>Move</td>
<td>Transmits the movement of clients, collision information and also the information about food capture.</td>
</tr>
</tbody>
</table>

The communication packets are encoded in byte format for the purpose of transmission and are decoded in similar fashion. The encoding and decoding of packets in client side is handled by ClientEncoder and ClientDecoder respectively. Similar for game server, encoding and decoding is handled by ServerEncoder and ServerDecoder respectively.

For instance, the server encoder for chat message is known as ChatServerEncoder. The encoders and decoders are placed under net.sf.isnake.codec.

On the basis of communication packet flow, we can classify the communication basically into two types:

- **Client Initiated Communication**: In this type of communication, the client first
encodes the packet with necessary data. Send it to server in flipped order. Flipping is required so that it gets received in correct order at the other end. The server decodes it. The server re-encodes the data with some further informations (if required such as sender's Id) and flips it. This packet is re-transmitted to clients where it is decoded. The communication cycle is shown below:

- **Server Initiated Communication**: In this type of communication, server first encodes the packet with necessary data and transmits in flipped order. The packet is decoded on client side. The communication cycle is shown below:

The five classes of communication can send various messages. All the messages are decoded the same way they are encoded. Following conventions are used in depicting the encoding over here:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; &gt;</td>
<td>Shows fields to be sent along with identifier</td>
</tr>
<tr>
<td>( )</td>
<td>Shows the data type of the field. However, all the fields are converted into byte while encoding and on decoding they are received as bytes and converted to proper data type.</td>
</tr>
<tr>
<td>id</td>
<td>Represents the player id (an integer used to uniquely identify a player in the game).</td>
</tr>
<tr>
<td>[ ]</td>
<td>The fields within [] are part of an array in the protocol class.</td>
</tr>
</tbody>
</table>

**Class: Chat Message**

<table>
<thead>
<tr>
<th></th>
<th>Packet</th>
<th>Chat Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identifier</td>
<td>CH</td>
</tr>
<tr>
<td></td>
<td>Type</td>
<td>Client Initiated</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Is used to transmit a chat message typed by a client to other clients. to_id is required for one to one communication which is not currently</td>
</tr>
</tbody>
</table>
allowed in the game but has been designed for future enhancements. 0 is being sent as to_id which is basically a multicast id.

<table>
<thead>
<tr>
<th>Class</th>
<th>Packet</th>
<th>Identifier</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class: Information</strong></td>
<td>1</td>
<td>IN</td>
<td>Client Initiated</td>
<td>Is used to transport the informations of a player viz; name, color and location.</td>
</tr>
<tr>
<td>ClientEncoder</td>
<td>CH&lt;to_id(byte)&gt; &lt;len_of_message(short)&gt; &lt;message(string)&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ServerEncoder</td>
<td>CH&lt;from_id(byte)&gt; &lt;to_id(byte)&gt; &lt;len_of_message(short)&gt; &lt;message(string)&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class: ControlSignal</th>
<th>1</th>
<th>AK</th>
<th>Client Initiated</th>
<th>This packet is sent when a client successfully receives Level data. The status_code field has been reserved for future enhancements. As of now it is sent as 0.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClientEncoder</td>
<td>AK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ServerEncoder</td>
<td>AK&lt;id(byte)&gt; &lt;status_code(byte)&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Packet</th>
<th>Identifier</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>QT</td>
<td></td>
<td>Quit</td>
</tr>
</tbody>
</table>

ClientEncoder: IN<info_len(short)> <name:color:location(string)>

ServerEncoder: IN<info_len(short)> <id:name:color:location(string)>
<table>
<thead>
<tr>
<th>Type</th>
<th>Client Initiated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Sent when a client quits the game.</td>
</tr>
<tr>
<td>ClientEncoder</td>
<td>QT</td>
</tr>
<tr>
<td>ServerEncoder</td>
<td>QT&lt;id(byte)&gt;</td>
</tr>
<tr>
<td>3 Packet</td>
<td>Ready</td>
</tr>
<tr>
<td>Identifier</td>
<td>RY</td>
</tr>
<tr>
<td>Type</td>
<td>Client Initiated</td>
</tr>
<tr>
<td>Description</td>
<td>Is sent when the user specifies his readiness to start the game.</td>
</tr>
<tr>
<td>ClientEncoder</td>
<td>RY</td>
</tr>
<tr>
<td>ServerEncoder</td>
<td>RY&lt;id(byte)&gt;&lt;status_code(byte)&gt;</td>
</tr>
<tr>
<td>4 Packet</td>
<td>ID</td>
</tr>
<tr>
<td>Identifier</td>
<td>ID</td>
</tr>
<tr>
<td>Type</td>
<td>Server Initiated</td>
</tr>
<tr>
<td>Description</td>
<td>This packet is sent by server to client to assign an id to the player. This is done as soon as the client sends his information.</td>
</tr>
<tr>
<td>ServerEncoder</td>
<td>ID&lt;id(byte)&gt;</td>
</tr>
<tr>
<td>5 Packet</td>
<td>Start</td>
</tr>
<tr>
<td>Identifier</td>
<td>ST</td>
</tr>
<tr>
<td>Type</td>
<td>Server Initiated</td>
</tr>
<tr>
<td>Description</td>
<td>Represents start of various events in the game on the basis of status_code. status_code 0 represents the beginning of transmission of level data. status_code 1 represents the beginning of</td>
</tr>
</tbody>
</table>
level synchronization task before beginning of a level and status_code 2 is a signal to start the actual level play.

<table>
<thead>
<tr>
<th>ServerEncoder</th>
<th>ST&lt;status_code(byte)&gt;</th>
</tr>
</thead>
</table>

| Packet | Stop |
| Identifier | SP |
| Type | Server Initiated |
| Description | Represents the end of level. |
| ServerEncoder | SP<status_code(byte)> |

| Packet | Force |
| Identifier | FR |
| Type | Server Initiated |
| Description | This communication packet forces a player to send a ready packet when all others have expressed their willingness to begin the game. |
| ServerEncoder | FR<id(byte)><status_code(byte)> |

<p>| Packet | No Acknowledgment |
| Identifier | NK |
| Type | Server Initiated |
| Description | This packet is sent by server when the information supplied by client is not valid. status_code here represents field which has invalid data. Invalid data occurs when information field contains reserved characters or duplicate entry. |
| ServerEncoder | NK&lt;id(byte)&gt;&lt;status_code(byte)&gt; |</p>
<table>
<thead>
<tr>
<th></th>
<th>Packet</th>
<th>Description</th>
<th>Identifier</th>
<th>ServerEncoder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Begin from</td>
<td>The packet sends starting coordinate of all the players in a single packet. The player begins level from this coordinate and is reset to this coordinate on collision.</td>
<td>BF</td>
<td>BF&lt;3*no_of_players(byte)&gt;[&lt;id(byte)&gt;&lt;x_coordinate(byte)&gt;&lt;y_coordinate(byte)&gt;]</td>
</tr>
<tr>
<td>2</td>
<td>Score</td>
<td>Sends score of all the players in the packet on beginning of a level.</td>
<td>SC</td>
<td>SC&lt;8<em>2</em>no_of_players(byte)&gt;[&lt;id(long)&gt;&lt;score(long)&gt;]</td>
</tr>
<tr>
<td>3</td>
<td>Level</td>
<td>Sends the level number to the clients.</td>
<td>LV</td>
<td>LV&lt;level_number(byte)&gt;</td>
</tr>
<tr>
<td>4</td>
<td>Life</td>
<td></td>
<td>LF</td>
<td></td>
</tr>
<tr>
<td>Packet</td>
<td>Description</td>
<td>ServerEncoder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Wall</td>
<td>LF&lt;2*no_of_players(byte)&gt;[&lt;id(byte)&gt;&lt;life_count(byte)&gt;]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identifier</td>
<td>WL</td>
<td>Type</td>
<td>Server Initiated</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>Sends the wall coordinates to the clients.</td>
<td>ServerEncoder</td>
<td>WL&lt;2*wall_length(short)&gt;[&lt;x_coordinate(byte)&gt;&lt;y_coordinate(byte)&gt;]</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Food</td>
<td>Identifier</td>
<td>FD</td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Server Initiated</td>
<td>Description</td>
<td>Sends the food coordinates to the clients on the beginning of a level.</td>
<td>ServerEncoder</td>
</tr>
</tbody>
</table>

**Class: Move**

<table>
<thead>
<tr>
<th>Packet</th>
<th>Description</th>
<th>Identifier</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Collide</td>
<td>CL</td>
<td>Client Initiated</td>
<td>The packet is sent when a player looses a life. Possibility of more than one players colliding on same turn has been taken into account. At present, however, we are checking the collision on server and the communication is thus Server Initiated.</td>
</tr>
<tr>
<td>Packet</td>
<td>Identifier</td>
<td>Type</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
<td>------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Move</td>
<td></td>
<td>Client Initiated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MV</td>
<td></td>
<td>Carries the change in x and y (dx,dy) of the clients to the server. Server merges change in coordinate of all the clients in a new MV packet and transmits to the clients.</td>
<td></td>
</tr>
<tr>
<td>ClientEncoder</td>
<td>MV[&lt;id(byte)&gt;&lt;dx(byte)&gt;&lt;dy(byte)&gt;]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ServerEncoder</td>
<td>MV&lt;3*no_of_players(byte)&gt;[&lt;id(byte)&gt;&lt;dx(byte)&gt;&lt;dy(byte)&gt;]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Eaten</td>
<td></td>
<td>Server Initiated</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ET</td>
<td></td>
<td>Server sends the packet whenever the food gets eaten. This packet also initiates the generation of Food packet as a level can have more than one food.</td>
<td></td>
</tr>
<tr>
<td>ClientEncoder</td>
<td>ET</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ServerEncoder</td>
<td>ET&lt;eaten_id(byte)&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FD[&lt;x_coordinate(byte)&gt;&lt;y_coordinate(byte)&gt;]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>