

```
Za = 0.9995922115;
```

```
rhovs = 0.00985938;
```

```
R = 8.314472;
```

```
Mv = 0.018015;
```

```
ras = 1e-8 * (k1 / (k0 - S) + k3 / (k2 - S));
```

```
rvs = 1.022e-8 * (w0 + w1 * S + w2 * S ** 2 + w3 * S ** 3);
```

```
Ma = 0.0289635 + 1.2011e-8 * (xC02 - 400);
```

```
raxs = ras * (1 + 5.34e-7 * (xC02 - 450));
```

```
Zm = 1 - (x2 / T) * (a0 + a1 * x1 + a2 * x1 ** 2 + (b0 + b1 * x1) * x2);
```

```
rhoaxs = pR1 * Ma / (Za * R * TR1);
```

```
rhov = xv * x2 * Mv / (Zm * R * T);
```

```
rhoa = (1 - xv) * x2 * Ma / (Zm * R * T);
```

```
nr = 1 + (rhoa / rhoaxs) * raxs + (rhov / rhovs) * rvs;
```

```
return nr;
```

**TECHNICAL!!**

1  
00:00:05,930 --> 00:00:03,590  
hey this is my quest of medibang gorg if

2  
00:00:07,610 --> 00:00:05,940  
you think my videos are a bit too

3  
00:00:09,080 --> 00:00:07,620  
technical sometimes then you should

4  
00:00:10,339 --> 00:00:09,090  
probably stop watching now because this

5  
00:00:13,009 --> 00:00:10,349  
is going to be a very very very

6  
00:00:16,220 --> 00:00:13,019  
technical video what I'm going to do is

7  
00:00:18,680 --> 00:00:16,230  
I'm going to explain how this refraction

8  
00:00:20,450 --> 00:00:18,690  
simulator that I wrote actually works

9  
00:00:22,790 --> 00:00:20,460  
I'm going to have a look at the source

10  
00:00:25,460 --> 00:00:22,800  
code and the mathematics and the

11  
00:00:27,769 --> 00:00:25,470  
equations behind it and I'll try to do

12  
00:00:29,450 --> 00:00:27,779  
it reasonably quickly so you can just

13  
00:00:31,130 --> 00:00:29,460

look at the actual stuff yourself

14

00:00:35,950 --> 00:00:31,140

hopefully I should give you enough of an

15

00:00:38,930 --> 00:00:35,960

understanding so refraction simulator is

16

00:00:41,660 --> 00:00:38,940

basically simulating the effects of

17

00:00:45,619 --> 00:00:41,670

atmospheric refraction and you see here

18

00:00:48,319 --> 00:00:45,629

we have rays of light which are coming

19

00:00:51,410 --> 00:00:48,329

from the camera this is using the

20

00:00:52,910 --> 00:00:51,420

principle of reversibility of light goes

21

00:00:55,130 --> 00:00:52,920

exactly the same way through air

22

00:00:56,569 --> 00:00:55,140

regardless of whether you go this way or

23

00:00:59,150 --> 00:00:56,579

this way now of course light is actually

24

00:01:01,010 --> 00:00:59,160

going from the target to the camera but

25

00:01:02,599 --> 00:01:01,020

we can actually cast rays from the

26

00:01:07,520 --> 00:01:02,609

camera to the target and it goes along

27

00:01:10,700 --> 00:01:07,530

the same path so what we want to do in

28

00:01:13,460 --> 00:01:10,710

terms of code is that we start out from

29

00:01:17,390 --> 00:01:13,470

a position over here where the camera is

30

00:01:19,550 --> 00:01:17,400

and we give the Ray a direction which

31

00:01:20,960 --> 00:01:19,560

and it's like in tentacle now I use a

32

00:01:22,969 --> 00:01:20,970

two-dimensional vector

33

00:01:25,550 --> 00:01:22,979

I just use a two-dimensional unit vector

34

00:01:27,770 --> 00:01:25,560

which is a vector of length 1 and that

35

00:01:31,370 --> 00:01:27,780

specifies which way the line is pointing

36

00:01:34,010 --> 00:01:31,380

and I store its position as another 2d

37

00:01:35,660 --> 00:01:34,020

vector and X Y vector where X is the

38

00:01:39,950 --> 00:01:35,670

horizontal distance and Y is the

39

00:01:43,730 --> 00:01:39,960

vertical distance 0 0 in this situation

40

00:01:45,440 --> 00:01:43,740

is the ground beneath the feet of the

41

00:01:47,899 --> 00:01:45,450

where the guy with a camera is

42

00:01:52,550 --> 00:01:47,909

theoretically sending so if we move in

43

00:01:55,850 --> 00:01:52,560

way up here 0 0 in our coordinate system

44

00:02:01,020 --> 00:01:55,860

is this position right here and so this

45

00:02:06,510 --> 00:02:03,860

the nuts and bolts of the code are

46

00:02:08,460 --> 00:02:06,520

tracing a ray which means we start with

47

00:02:12,300 --> 00:02:08,470

a ray a certain position which we call P

48

00:02:14,690 --> 00:02:12,310

and we have a direction which I specify

49

00:02:17,370 --> 00:02:14,700

with a unit vector which I call you and

50

00:02:22,199 --> 00:02:17,380

I trace it forward one step at a time

51  
00:02:24,330 --> 00:02:22,209  
along a distance  $D$  and we move through

52  
00:02:25,800 --> 00:02:24,340  
this medium which is a varying

53  
00:02:29,370 --> 00:02:25,810  
refractive index and the actual

54  
00:02:32,160 --> 00:02:29,380  
refractive index affects how the ray

55  
00:02:34,560 --> 00:02:32,170  
actually curves so we move it a step

56  
00:02:35,970 --> 00:02:34,570  
forward we see as it moved up or down a

57  
00:02:38,010 --> 00:02:35,980  
little bit and then we move it up or

58  
00:02:39,240 --> 00:02:38,020  
down and then we move it again and we

59  
00:02:41,420 --> 00:02:39,250  
keep moving and eventually we'll hit

60  
00:02:45,570 --> 00:02:41,430  
something and then where we hit it

61  
00:02:49,190 --> 00:02:45,580  
determines what red watch line of the

62  
00:02:51,540 --> 00:02:49,200  
image ends up in the final result so

63  
00:02:54,449 --> 00:02:51,550

probably lost you all already but I'm

64

00:02:57,180 --> 00:02:54,459

gonna plow on now if you want to see how

65

00:03:01,710 --> 00:02:57,190

this simulator actually works then you

66

00:03:04,250 --> 00:03:01,720

have to look at the source code and here

67

00:03:07,470 --> 00:03:04,260

in chrome I can just go to view

68

00:03:09,509 --> 00:03:07,480

developer view source and the source

69

00:03:12,479 --> 00:03:09,519

code will pop up blah blah blah it's all

70

00:03:15,660 --> 00:03:12,489

there but actually a couple of other

71

00:03:19,500 --> 00:03:15,670

files which you can see listed at the

72

00:03:22,140 --> 00:03:19,510

top let's see they're gonna be right

73

00:03:23,820 --> 00:03:22,150

here you can click on them to just load

74

00:03:26,039 --> 00:03:23,830

them and then you can you can see them

75

00:03:29,460 --> 00:03:26,049

here but another way of doing this is in

76

00:03:32,490 --> 00:03:29,470

chrome you do view developer and

77

00:03:35,160 --> 00:03:32,500

developer tools and it will bring you up

78

00:03:36,600 --> 00:03:35,170

this little list neat neatly shows kind

79

00:03:38,759 --> 00:03:36,610

of the project structure and where the

80

00:03:42,240 --> 00:03:38,769

other files are jQuery is a strong that

81

00:03:44,370 --> 00:03:42,250

standard library library the action most

82

00:03:48,870 --> 00:03:44,380

of the code is actually in the index

83

00:03:50,610 --> 00:03:48,880

file index.html and most of the actual

84

00:03:54,420 --> 00:03:50,620

interesting code is in there some other

85

00:03:56,490 --> 00:03:54,430

stuff is in this file here pseudo ID and

86

00:03:58,710 --> 00:03:56,500

refraction GS which has a few equations

87

00:04:00,810 --> 00:03:58,720

for calculating refractive index then

88

00:04:03,720 --> 00:04:00,820

the curve editor which is a thing I

89

00:04:05,370 --> 00:04:03,730

wrote to easily edit the actual curves

90

00:04:07,800 --> 00:04:05,380

it's not very complicated it's just

91

00:04:10,530 --> 00:04:07,810

Bezier curves which I guess is

92

00:04:12,479 --> 00:04:10,540

complicated but you know that's these

93

00:04:13,660 --> 00:04:12,489

are the only extra bits of code that are

94

00:04:15,400 --> 00:04:13,670

relevant but

95

00:04:17,830 --> 00:04:15,410

I wrote this is just an implementation

96

00:04:19,810 --> 00:04:17,840

of standard equations and this is just

97

00:04:22,680 --> 00:04:19,820

editing a curve right back to the index

98

00:04:25,900 --> 00:04:22,690

I'm actually going to show you this in

99

00:04:27,700 --> 00:04:25,910

the program I use which piece phpstorm

100

00:04:31,030 --> 00:04:27,710

and I've made the font nice and big so

101  
00:04:33,190 --> 00:04:31,040  
you can see you can see what what's

102  
00:04:35,980 --> 00:04:33,200  
actually going on so the heart of the

103  
00:04:39,879 --> 00:04:35,990  
program is this one function here trace

104  
00:04:43,780 --> 00:04:39,889  
one line and it's taking a line number

105  
00:04:47,590 --> 00:04:43,790  
which is actually the line number of the

106  
00:04:50,890 --> 00:04:47,600  
the actual target image which would be

107  
00:04:52,750 --> 00:04:50,900  
when I was the the resultant image the

108  
00:04:56,830 --> 00:04:52,760  
rendered image so the line on the screen

109  
00:04:59,020 --> 00:04:56,840  
basically so it's my life checking to

110  
00:05:01,450 --> 00:04:59,030  
see if it's being done already is it

111  
00:05:04,270 --> 00:05:01,460  
just things asynchronously so it will do

112  
00:05:05,710 --> 00:05:04,280  
like every one out of ten lines and then

113  
00:05:08,710 --> 00:05:05,720

it Flags them as being done and there's

114

00:05:10,600 --> 00:05:08,720

an array called rays which contains all

115

00:05:12,730 --> 00:05:10,610

the lines and as a bunch of bunch of

116

00:05:14,800 --> 00:05:12,740

flags in but not that difficult

117

00:05:16,330 --> 00:05:14,810

not that complicated but you can look at

118

00:05:17,710 --> 00:05:16,340

the actual structure of the rays array

119

00:05:19,180 --> 00:05:17,720

and see the various of the four things

120

00:05:21,190 --> 00:05:19,190

in it

121

00:05:27,880 --> 00:05:21,200

we can I collect the angle of the Ray

122

00:05:29,140 --> 00:05:27,890

and now obviously when when array is

123

00:05:30,909 --> 00:05:29,150

leaving your eye goes out at a

124

00:05:33,040 --> 00:05:30,919

particular angle zero is going to be

125

00:05:35,110 --> 00:05:33,050

perfectly horizontal and this is going

126

00:05:37,450 --> 00:05:35,120

to be up at whatever the field of view

127

00:05:39,070 --> 00:05:37,460

is which is 1.5 degrees here remember

128

00:05:40,360 --> 00:05:39,080

this is greatly exaggerated so it looks

129

00:05:42,190 --> 00:05:40,370

like it's a fairly wide field of view

130

00:05:47,950 --> 00:05:42,200

it's only actually 1.5 degrees which is

131

00:05:50,710 --> 00:05:47,960

a very very narrow field of view it's

132

00:05:53,590 --> 00:05:50,720

taking x and y's being the star position

133

00:05:54,880 --> 00:05:53,600

there's just the the the eye x and y

134

00:05:59,740 --> 00:05:54,890

which is the basically the camera

135

00:06:02,170 --> 00:05:59,750

position and it takes this angle or

136

00:06:03,310 --> 00:06:02,180

whatever it's doing there I guess it's

137

00:06:05,350 --> 00:06:03,320

just check checking to see if you're

138

00:06:06,659 --> 00:06:05,360

going up or down coloring the Lions red

139

00:06:10,390 --> 00:06:06,669

or blue

140

00:06:13,180 --> 00:06:10,400

this is detecting which of the lines is

141

00:06:15,310 --> 00:06:13,190

eye level not very important really just

142

00:06:16,810 --> 00:06:15,320

cosmetic thing and here this is where we

143

00:06:22,810 --> 00:06:16,820

get to some of the actual mathematics

144

00:06:27,040 --> 00:06:22,820

here getting the value  $D$  to be the step

145

00:06:30,790 --> 00:06:27,050

along the the line which is how

146

00:06:33,939 --> 00:06:30,800

we're gonna go in one step in our ray

147

00:06:35,649 --> 00:06:33,949

tracing algorithm which is typically the

148

00:06:42,399 --> 00:06:35,659

distance to the target and divided by

149

00:06:47,339 --> 00:06:42,409

500 I think now we have the unit vector

150

00:06:50,559 --> 00:06:47,349

$U$  which is the direction of the Ray and

151  
00:06:53,770 --> 00:06:50,569  
we just use two variables  $u_x$  and  $u_y$  to

152  
00:06:55,149 --> 00:06:53,780  
store this and we calculating it simply

153  
00:06:57,640 --> 00:06:55,159  
as being the cosine and the negative

154  
00:06:59,950 --> 00:06:57,650  
sine of the angle and you want to think

155  
00:07:05,589 --> 00:06:59,960  
about how that actually works you can

156  
00:07:09,610 --> 00:07:05,599  
think of a actual vector  $d$   $DX$  and  $dy$

157  
00:07:12,969 --> 00:07:09,620  
which is the the length of  $D$  multiplied

158  
00:07:15,459 --> 00:07:12,979  
by the cosine and the negative sine of

159  
00:07:16,809 --> 00:07:15,469  
the angle and then you calculate the

160  
00:07:18,430 --> 00:07:16,819  
length of that and then you calculate

161  
00:07:21,219 --> 00:07:18,440  
the unit vector by dividing it by the

162  
00:07:23,320 --> 00:07:21,229  
length so this gives you the actual off

163  
00:07:26,439 --> 00:07:23,330

certainty but for our purposes we're

164

00:07:28,029 --> 00:07:26,449

only using the unit vector so we don't

165

00:07:29,680 --> 00:07:28,039

need to have these intermediate values

166

00:07:33,390 --> 00:07:29,690

which you might if you're doing it in a

167

00:07:37,570 --> 00:07:33,400

slightly different way all right

168

00:07:40,899 --> 00:07:37,580

so for this Ray we are going to build in

169

00:07:43,450 --> 00:07:40,909

an array of line points which is just

170

00:07:45,040 --> 00:07:43,460

point XY point and we're going to check

171

00:07:47,409 --> 00:07:45,050

to see if we hit the ground and we check

172

00:07:50,140 --> 00:07:47,419

to see if we recheck later to see if we

173

00:07:52,390 --> 00:07:50,150

hit the target this is how much we're

174

00:07:55,629 --> 00:07:52,400

actually going to trace we just

175

00:07:57,459 --> 00:07:55,639

basically trace the amount that is

176

00:08:00,809 --> 00:07:57,469

visible in this diagram here so we'll

177

00:08:03,100 --> 00:08:00,819

trace all the way over to here to see if

178

00:08:05,170 --> 00:08:03,110

you know we hit something we don't we

179

00:08:06,740 --> 00:08:05,180

just basically stop if we get it to this

180

00:08:11,090 --> 00:08:06,750

point

181

00:08:13,370 --> 00:08:11,100

and if it's a flat earth then we

182

00:08:15,220 --> 00:08:13,380

actually triple the amount that we trace

183

00:08:17,570 --> 00:08:15,230

because we want to see the horizon

184

00:08:19,660 --> 00:08:17,580

beyond things this isn't work entirely

185

00:08:22,190 --> 00:08:19,670

right and I need to improve that but

186

00:08:25,760 --> 00:08:22,200

that's why I'm doing that try to get a

187

00:08:31,190 --> 00:08:25,770

more accurate horizon beyond the actual

188

00:08:34,159 --> 00:08:31,200

target ok so this is the main loop that

189

00:08:36,800 --> 00:08:34,169

loops and calculates all of the points

190

00:08:40,700 --> 00:08:36,810

in the ray tracing this this function

191

00:08:42,110 --> 00:08:40,710

call here is the key thing and which

192

00:08:45,590 --> 00:08:42,120

will need the most explanation

193

00:08:48,170 --> 00:08:45,600

it takes us parameters x and y which is

194

00:08:50,960 --> 00:08:48,180

the current position it takes UX and uy

195

00:08:52,670 --> 00:08:50,970

which is the direction and it takes D

196

00:08:54,860 --> 00:08:52,680

which is how much of a step we're going

197

00:08:57,800 --> 00:08:54,870

to take so D times you actually uy will

198

00:08:59,980 --> 00:08:57,810

give you the new position and it calls

199

00:09:02,540 --> 00:08:59,990

this function here step forward and

200

00:09:05,260 --> 00:09:02,550

updates all the values if it hits the

201  
00:09:09,110 --> 00:09:05,270  
ground then it Flags it and then stops

202  
00:09:10,580 --> 00:09:09,120  
otherwise it adds a new point XY to the

203  
00:09:13,190 --> 00:09:10,590  
array of line points and just keeps

204  
00:09:14,990 --> 00:09:13,200  
going until this islet done or its hit

205  
00:09:18,260 --> 00:09:15,000  
hit the ground by done being going off

206  
00:09:20,690 --> 00:09:18,270  
the right hand side and that's pretty

207  
00:09:22,520 --> 00:09:20,700  
much it for that so let's delve into

208  
00:09:25,220 --> 00:09:22,530  
what step forward does this is the

209  
00:09:27,380 --> 00:09:25,230  
complicated bit if you don't think it's

210  
00:09:30,370 --> 00:09:27,390  
complicated enough already so I'm going

211  
00:09:33,050 --> 00:09:30,380  
to zip into that function step forward

212  
00:09:35,540 --> 00:09:33,060  
it's planes wait I see a given x and y

213  
00:09:41,810 --> 00:09:35,550

we're going to step forward by  $x$  times  $d$

214

00:09:43,820 --> 00:09:41,820

uy times  $d$  and blah blah blah so to

215

00:09:45,560 --> 00:09:43,830

explain how this works there's a venture

216

00:09:46,880 --> 00:09:45,570

this is what it actually does here to

217

00:09:50,140 --> 00:09:46,890

explain how this works I'm going to have

218

00:09:54,470 --> 00:09:50,150

to show you a diagram

219

00:10:00,530 --> 00:09:58,520

okay now if every country this base has

220

00:10:05,180 --> 00:10:00,540

simple integration of a point  $P$  of

221

00:10:10,100 --> 00:10:05,190

distance  $D$  in Direction  $u$  here's a point

222

00:10:11,960 --> 00:10:10,110

$P$  the point  $P$  is the point on a ray of

223

00:10:15,560 --> 00:10:11,970

light but really you've got to think of

224

00:10:17,660 --> 00:10:15,570

the motion of light as being the motion

225

00:10:20,030 --> 00:10:17,670

of a wavefront you see this squiggly

226

00:10:23,030 --> 00:10:20,040

line here it's meant to be a wavefront

227

00:10:26,180 --> 00:10:23,040

so it's the the ray of light is actually

228

00:10:29,660 --> 00:10:26,190

just one point on a wave that's going

229

00:10:32,050 --> 00:10:29,670

along and we have this point P on that

230

00:10:36,620 --> 00:10:32,060

wave and we want to know if it's gone up

231

00:10:40,160 --> 00:10:36,630

distance D along direction vector u what

232

00:10:42,770 --> 00:10:40,170

will be the new point P - which is

233

00:10:45,290 --> 00:10:42,780

sometimes called P Prime but old British

234

00:10:48,800 --> 00:10:45,300

so I'm calling it P - and what will be

235

00:10:51,740 --> 00:10:48,810

the new direction u - so the mathematics

236

00:10:56,000 --> 00:10:51,750

we're doing here is how do we take P and

237

00:10:58,010 --> 00:10:56,010

you and turn it into P - and you - so

238

00:11:00,980 --> 00:10:58,020

the old way I did it was that I would

239

00:11:03,860 --> 00:11:00,990

calculates two points a and B on either

240

00:11:07,010 --> 00:11:03,870

side a B either side of p on this

241

00:11:09,530 --> 00:11:07,020

wavefront then I would calculate the

242

00:11:13,610 --> 00:11:09,540

points a dash and B dash and the way I

243

00:11:15,230 --> 00:11:13,620

do that is that a and B will be in

244

00:11:18,260 --> 00:11:15,240

different parts of the medium so they're

245

00:11:20,990 --> 00:11:18,270

in different refractive indices the

246

00:11:23,860 --> 00:11:21,000

refractive index will be different for a

247

00:11:28,430 --> 00:11:23,870

and B so it'll move at different speeds

248

00:11:31,550 --> 00:11:28,440

through through this the speed of light

249

00:11:33,260 --> 00:11:31,560

in a medium is inversely proportional to

250

00:11:35,750 --> 00:11:33,270

the refractive index so you have to

251  
00:11:38,480 --> 00:11:35,760  
divide the speed of light by the

252  
00:11:39,800 --> 00:11:38,490  
refractive index and that gives you the

253  
00:11:41,060 --> 00:11:39,810  
actual speed of light and that tell you

254  
00:11:44,210 --> 00:11:41,070  
how far it can go

255  
00:11:45,740 --> 00:11:44,220  
so this point P will move based on

256  
00:11:48,350 --> 00:11:45,750  
whatever the refractive index is here

257  
00:11:50,060 --> 00:11:48,360  
this point a will move based on whether

258  
00:11:52,250 --> 00:11:50,070  
the refractive index is here and end up

259  
00:11:54,170 --> 00:11:52,260  
in a - so you could calculate these two

260  
00:11:57,350 --> 00:11:54,180  
points a and B's and calculate some new

261  
00:11:59,270 --> 00:11:57,360  
points a dash and B dash and then that

262  
00:12:01,670 --> 00:11:59,280  
would give you this line here and you

263  
00:12:03,470 --> 00:12:01,680

can use this line here to find out what

264

00:12:04,790 --> 00:12:03,480

the new you - would be because it's

265

00:12:07,850 --> 00:12:04,800

simply the vector which is perpendicular

266

00:12:11,900 --> 00:12:07,860

to this line

267

00:12:14,299 --> 00:12:11,910

I do us something of a an optimization

268

00:12:17,629 --> 00:12:14,309

or a simplification here instead of

269

00:12:23,199 --> 00:12:17,639

calculating these points a and B I just

270

00:12:28,220 --> 00:12:23,209

directly calculate the value of U from

271

00:12:32,809 --> 00:12:28,230

this value G where G is the unit

272

00:12:37,389 --> 00:12:32,819

gradient of the refractive index field

273

00:12:41,869 --> 00:12:37,399

at P that's the UM perhaps a little bit

274

00:12:44,809 --> 00:12:41,879

hard to understand like I said it's from

275

00:12:47,569 --> 00:12:44,819

your brother hard to understand but the

276

00:12:51,519 --> 00:12:47,579

refractive index gradient that is how

277

00:12:57,079 --> 00:12:51,529

much is how much is the value of N

278

00:12:58,970 --> 00:12:57,089

changing in the X direction and in the

279

00:13:05,749 --> 00:12:58,980

in the X direction and in the Y

280

00:13:08,569 --> 00:13:05,759

direction per foot and that is a value G

281

00:13:11,239 --> 00:13:08,579

which is a vector value obviously to GX

282

00:13:12,650 --> 00:13:11,249

and Gy because it's how much is it

283

00:13:14,269 --> 00:13:12,660

changing X and what's is changing and

284

00:13:16,579 --> 00:13:14,279

why it's represented by an arrow here

285

00:13:19,929 --> 00:13:16,589

because it's going to be a direction it

286

00:13:21,980 --> 00:13:19,939

will be not necessarily a unit vector

287

00:13:24,079 --> 00:13:21,990

because it will have a certain length

288

00:13:31,189 --> 00:13:24,089

and the steeper the gradient the longer

289

00:13:33,889 --> 00:13:31,199

this this  $G$  will be so the method is not

290

00:13:36,259 --> 00:13:33,899

too long but it's perhaps difficult to

291

00:13:37,999 --> 00:13:36,269

understand so let's go through it  $U$  is

292

00:13:39,350 --> 00:13:38,009

the unit vector or the rate direction we

293

00:13:42,199 --> 00:13:39,360

already know that it's this value here

294

00:13:45,139 --> 00:13:42,209

it's the unit vector along this this

295

00:13:47,840 --> 00:13:45,149

line of travel  $P$  is the current rate

296

00:13:49,549 --> 00:13:47,850

where are we starting  $a$  and  $B$  are two

297

00:13:54,439 --> 00:13:49,559

points on the way from perpendicular to

298

00:13:56,119 --> 00:13:54,449

$u$  which they're going to be virtual

299

00:13:59,809 --> 00:13:56,129

points but right now imagine they are

300

00:14:02,509 --> 00:13:59,819

actually real points  $V$  now I see  $V$  as a

301

00:14:04,879 --> 00:14:02,519

- as a little underscore which means

302

00:14:08,059 --> 00:14:04,889

that it's a vector quantity  $V$  is the

303

00:14:10,340 --> 00:14:08,069

left rotated you so here's you and

304

00:14:14,600 --> 00:14:10,350

here's  $V$  it's rotated counterclockwise

305

00:14:18,110 --> 00:14:14,610

to the left by 90 degrees so it's the

306

00:14:20,480 --> 00:14:18,120

vector perpendicular to - you

307

00:14:24,079 --> 00:14:20,490

is the refractive index at  $P$  so it's the

308

00:14:29,299 --> 00:14:24,089

refractive index at this position here  $G$

309

00:14:31,100 --> 00:14:29,309

as with it is the gradient of  $n$  at  $P$  now

310

00:14:34,009 --> 00:14:31,110

this is just explaining how you

311

00:14:36,860 --> 00:14:34,019

calculate rotated right and rotated left

312

00:14:41,210 --> 00:14:36,870

values rotate right it's just simply hue

313

00:14:43,280 --> 00:14:41,220

I minus X and rotate left is minus y

314

00:14:44,509 --> 00:14:43,290

minus X and let's explain why there's a

315

00:14:47,780 --> 00:14:44,519

little diagram here I should be fairly

316

00:14:50,629 --> 00:14:47,790

straightforward alright so as we have

317

00:14:54,410 --> 00:14:50,639

all these values we can figure out

318

00:14:58,670 --> 00:14:54,420

certain things we know that a is P plus

319

00:15:01,910 --> 00:14:58,680

B we're going to use an offset of 1 so

320

00:15:04,369 --> 00:15:01,920

we just use the unit vector to get the

321

00:15:05,989 --> 00:15:04,379

natural position of a and the B of

322

00:15:07,670 --> 00:15:05,999

course is P minus V because it's just in

323

00:15:15,170 --> 00:15:07,680

the other direction then we can

324

00:15:25,299 --> 00:15:15,180

calculate a dash as people's v8 a she's

325

00:15:29,419 --> 00:15:25,309

a plus u times D multiplied by n plus GB

326

00:15:32,169 --> 00:15:29,429

this is this is very frank it's a little

327

00:15:38,210 --> 00:15:32,179

confused but basically what that does is

328

00:15:42,259 --> 00:15:38,220

it takes the position a and he adds u

329

00:15:45,319 --> 00:15:42,269

times D scaled by a you deal with this

330

00:15:49,100 --> 00:15:45,329

lengthier from P - P - scaled by the

331

00:15:54,980 --> 00:15:49,110

refractive index at P which is n plus G

332

00:16:00,139 --> 00:15:54,990

dot V which is the component of G along

333

00:16:01,999 --> 00:16:00,149

V and which gives you how much the

334

00:16:06,079 --> 00:16:02,009

refractive index is changing in this

335

00:16:08,269 --> 00:16:06,089

direction from P to a and similarly we

336

00:16:11,629 --> 00:16:08,279

do the same thing for our B - we take B

337

00:16:15,590 --> 00:16:11,639

and we add u times D which is this

338

00:16:19,220 --> 00:16:15,600

vector scaled by  $n - G \cdot V$  which is

339

00:16:22,340 --> 00:16:19,230

going to be how much  $G$  varies in this

340

00:16:25,400 --> 00:16:22,350

direction so that will actually give you

341

00:16:29,030 --> 00:16:25,410

a virtual  $a$  and  $B$  so now we can

342

00:16:31,820 --> 00:16:29,040

calculate another vector  $B - a$  - which

343

00:16:35,840 --> 00:16:31,830

is this one here which is

344

00:16:37,550 --> 00:16:35,850

to be  $a - B$  - which if you take these

345

00:16:41,840 --> 00:16:37,560

just works out to be something nice

346

00:16:46,490 --> 00:16:41,850

which doesn't involve  $a$  or  $b$  so  $-v + 2$

347

00:16:49,250 --> 00:16:46,500

UD times govt and we can work out quite

348

00:16:51,350 --> 00:16:49,260

simply that you - which is the new unit

349

00:16:56,540 --> 00:16:51,360

vector in this direction is the right

350

00:16:58,340 --> 00:16:56,550

rotated vector  $B - a$  so it is  $B - a$  is

351  
00:17:00,080 --> 00:16:58,350  
that vector and then we were setting it

352  
00:17:01,970 --> 00:17:00,090  
right 90 degrees and then we take the

353  
00:17:03,710 --> 00:17:01,980  
unit vector which is what I'm indicating

354  
00:17:07,100 --> 00:17:03,720  
with these bars on either side and that

355  
00:17:09,560 --> 00:17:07,110  
gives you a new direction vector which

356  
00:17:13,460 --> 00:17:09,570  
gives us this nice little equation here

357  
00:17:19,180 --> 00:17:13,470  
you - you write rotated  $V + UD$  terms

358  
00:17:24,140 --> 00:17:19,190  
govt which slightly simplifies to this

359  
00:17:27,740 --> 00:17:24,150  
you - is  $U$  plus  $V$  times  $D$  times  $G$  dot  $V$

360  
00:17:33,560 --> 00:17:27,750  
because the  $U$  and  $V$  are the right

361  
00:17:36,470 --> 00:17:33,570  
rotated versions of  $V$  and  $u$  then we have

362  
00:17:38,630 --> 00:17:36,480  
simply  $P$  - is  $P$  Plus  $u$  times  $D$  now we

363  
00:17:42,080 --> 00:17:38,640

could multiply that by n times P but it

364

00:17:43,400 --> 00:17:42,090

doesn't really matter because the it

365

00:17:44,660 --> 00:17:43,410

doesn't really make much difference but

366

00:17:46,880 --> 00:17:44,670

I think I do actually do this very much

367

00:17:48,470 --> 00:17:46,890

not sure but if you can introduce this

368

00:17:51,110 --> 00:17:48,480

term into the code it doesn't really

369

00:17:52,880 --> 00:17:51,120

make very much difference all right now

370

00:17:56,030 --> 00:17:52,890

if thoroughly confuse everybody we can

371

00:17:58,660 --> 00:17:56,040

go back to the code and we can see that

372

00:18:02,810 --> 00:17:58,670

what we have is just simply an

373

00:18:07,580 --> 00:18:02,820

implementation of those equations we

374

00:18:11,930 --> 00:18:07,590

have NeoGeo v DG v and then you witness

375

00:18:16,750 --> 00:18:11,940

the new ux 1 UI 1 which is the work you

376

00:18:18,860 --> 00:18:16,760

do for you - calculated here and then

377

00:18:20,960 --> 00:18:18,870

normalizing it here by dividing by the

378

00:18:23,270 --> 00:18:20,970

length and then returning it and doing

379

00:18:26,480 --> 00:18:23,280

at x equals ya I don't actually add in

380

00:18:27,800 --> 00:18:26,490

the refractive index - you can you try

381

00:18:29,510 --> 00:18:27,810

it with them without but it doesn't

382

00:18:31,930 --> 00:18:29,520

actually make any difference so I left

383

00:18:36,550 --> 00:18:31,940

it off for speed

384

00:18:39,790 --> 00:18:36,560

ok that is how that works now

385

00:18:41,650 --> 00:18:39,800

I must admit it's very complicated

386

00:18:44,050 --> 00:18:41,660

sounding I wouldn't expect most people

387

00:18:47,170 --> 00:18:44,060

to understand it but if you want to

388

00:18:49,630 --> 00:18:47,180

understand how the code works then

389

00:18:51,360 --> 00:18:49,640

hopefully that would lead you through it

390

00:18:55,750 --> 00:18:51,370

and you can go through it step by step

391

00:18:57,870 --> 00:18:55,760

and follow along with what I just did

392

00:19:00,690 --> 00:18:57,880

and check the math and then see that

393

00:19:08,920 --> 00:19:00,700

these equations hearings step forward

394

00:19:13,060 --> 00:19:08,930

match that math okay so other things in

395

00:19:14,560 --> 00:19:13,070

the code that are math related are how

396

00:19:19,030 --> 00:19:14,570

do we actually calculate the refractive

397

00:19:24,370 --> 00:19:19,040

index the refractive index is calculated

398

00:19:26,020 --> 00:19:24,380

let's see in this function somewhere

399

00:19:27,520 --> 00:19:26,030

here it uses this function here gradient

400

00:19:29,770 --> 00:19:27,530

because we're using the gradient of the

401  
00:19:32,350 --> 00:19:29,780  
refractive index so how do we calculate

402  
00:19:36,220 --> 00:19:32,360  
the gradient of  $G_x$  and  $G_y$  we go into

403  
00:19:38,380 --> 00:19:36,230  
that and we see gradient  $x$  and  $y$  is just

404  
00:19:41,260 --> 00:19:38,390  
simply taking the refractive index

405  
00:19:42,880 --> 00:19:41,270  
that's half a foot on either side and

406  
00:19:46,030 --> 00:19:42,890  
then returning the difference between

407  
00:19:48,310 --> 00:19:46,040  
them and that gives you the gradient for

408  
00:19:51,040 --> 00:19:48,320  
the  $X$  and the gradient for the  $Y$  so it's

409  
00:19:53,020 --> 00:19:51,050  
very very simple really so what does

410  
00:19:55,990 --> 00:19:53,030  
this function do refractive index let's

411  
00:19:58,270 --> 00:19:56,000  
pop into that one I call this function

412  
00:20:02,320 --> 00:19:58,280  
here which is refractive index from  $H$

413  
00:20:05,140 --> 00:20:02,330

and that function here is always a it's

414

00:20:09,280 --> 00:20:05,150

a virtual function that it actually

415

00:20:11,890 --> 00:20:09,290

comes from this or this function here

416

00:20:14,950 --> 00:20:11,900

which calculates the function which

417

00:20:18,640 --> 00:20:14,960

ultimately calls this function here

418

00:20:20,530 --> 00:20:18,650

refractive index old which the oldest

419

00:20:24,580 --> 00:20:20,540

indicators before I did all this this

420

00:20:27,580 --> 00:20:24,590

fancy optimization and and or or they're

421

00:20:31,750 --> 00:20:27,590

doing a bit of a bit of a camel ROM

422

00:20:34,890 --> 00:20:31,760

spline interpolation down here which is

423

00:20:37,570 --> 00:20:34,900

an optimization so the actual relevant

424

00:20:40,630 --> 00:20:37,580

code for how we calculate the refractive

425

00:20:48,400 --> 00:20:40,640

index is in refractive index old which

426  
00:20:49,850 --> 00:20:48,410  
is right here which just takes the drop

427  
00:20:52,430 --> 00:20:49,860  
into account to calculate the height

428  
00:20:55,130 --> 00:20:52,440  
above the surface it calls pressure at

429  
00:20:56,780 --> 00:20:55,140  
altitude to calculate what's that

430  
00:21:00,770 --> 00:20:56,790  
pressure would be at that altitude which

431  
00:21:05,840 --> 00:21:00,780  
uses this equation here which comes from

432  
00:21:09,919 --> 00:21:05,850  
this Wikipedia page it calculates the

433  
00:21:11,630 --> 00:21:09,929  
temperature from the curve from this

434  
00:21:13,130 --> 00:21:11,640  
curve here you have to look in the it's

435  
00:21:15,140 --> 00:21:13,140  
just basically interpolating along this

436  
00:21:21,620 --> 00:21:15,150  
curve is very simple nothing complicated

437  
00:21:25,190 --> 00:21:21,630  
there it takes the RH from the default

438  
00:21:27,799 --> 00:21:25,200

RH if you know editing the RH which will

439

00:21:29,960 --> 00:21:27,809

be 50 generally if you are aged in the

440

00:21:31,760 --> 00:21:29,970

RH it comes from this graph here and

441

00:21:34,520 --> 00:21:31,770

similarly it's interpolated along that

442

00:21:36,560 --> 00:21:34,530

curve and then the refractive index is

443

00:21:38,810 --> 00:21:36,570

calculated from that temperature and the

444

00:21:42,289 --> 00:21:38,820

pressure and the RH by calling this

445

00:21:45,919 --> 00:21:42,299

function here air index Sidor which if

446

00:21:49,610 --> 00:21:45,929

we go into that we can see is the full

447

00:21:51,380 --> 00:21:49,620

Sidor equation from NIST website which

448

00:21:53,710 --> 00:21:51,390

is sudo is well known in the scientific

449

00:21:55,850 --> 00:21:53,720

literature as being the most accurate

450

00:21:58,159 --> 00:21:55,860

equation but of course it's incredibly

451  
00:21:59,630 --> 00:21:58,169  
complicated there's actually other

452  
00:22:01,370 --> 00:21:59,640  
equations you can use in here there's

453  
00:22:03,560 --> 00:22:01,380  
the application which is a bit simpler

454  
00:22:05,510 --> 00:22:03,570  
or there's this missed shot fourth

455  
00:22:08,419 --> 00:22:05,520  
equation which is relatively simple and

456  
00:22:12,740 --> 00:22:08,429  
straightforward but that essentially is

457  
00:22:13,430 --> 00:22:12,750  
all the math that is relevant in in the

458  
00:22:15,860 --> 00:22:13,440  
simulator

459  
00:22:18,230 --> 00:22:15,870  
so if hopefully that will explain to

460  
00:22:21,919 --> 00:22:18,240  
people who want to know who put in the

461  
00:22:24,380 --> 00:22:21,929  
time how it actually works and if you

462  
00:22:27,500 --> 00:22:24,390  
want to replicate it or if you want to

463  
00:22:29,270 --> 00:22:27,510

verify to if you want to improve it then

464

00:22:32,570 --> 00:22:29,280

it should give you a good understanding

465

00:22:33,860 --> 00:22:32,580

of the technical details behind it

466

00:22:35,470 --> 00:22:33,870

there's other stuff like how it does the

467

00:22:38,930 --> 00:22:35,480

rendering but that's just you know

468

00:22:40,789 --> 00:22:38,940

straightforward programming and just

469

00:22:44,080 --> 00:22:40,799

basically data management it's not

470

00:22:47,600 --> 00:22:44,090

really pretty interesting the actual

471

00:22:49,640 --> 00:22:47,610

technical stuff is this stuff right here

472

00:22:51,530 --> 00:22:49,650

the mathematics the equations the

473

00:22:55,150 --> 00:22:51,540

implementation of the those equations

474

00:22:59,120 --> 00:22:55,160

and how we step through them with our

475

00:23:02,659 --> 00:22:59,130

gradient there's various issues with it

476

00:23:03,710 --> 00:23:02,669

like the step size the calculation of

477

00:23:07,970 --> 00:23:03,720

the gradient

478

00:23:10,610 --> 00:23:07,980

is based on a step of one and you know

479

00:23:13,909 --> 00:23:10,620

things could be improved and it's not

480

00:23:15,770 --> 00:23:13,919

the same as the the the formula that

481

00:23:17,960 --> 00:23:15,780

Andy Young and Walter bisland used which

482

00:23:22,070 --> 00:23:17,970

uses curved segments but that is based

483

00:23:23,600 --> 00:23:22,080

on a much simpler version of the

484

00:23:25,430 --> 00:23:23,610

refractive index essentially it's using

485

00:23:26,930 --> 00:23:25,440

this very simple calculation which

486

00:23:28,580 --> 00:23:26,940

doesn't really use the full suit or

487

00:23:30,560 --> 00:23:28,590

equation so even though it's more

488

00:23:32,690 --> 00:23:30,570

accurate in some ways and it's going

489

00:23:33,980 --> 00:23:32,700

through a curve it's less accurate in

490

00:23:36,020 --> 00:23:33,990

this using this very very simple

491

00:23:40,220 --> 00:23:36,030

equation which is more resembles more

492

00:23:42,950 --> 00:23:40,230

the NIST equation here alright so I'm

493

00:23:46,039 --> 00:23:42,960

going to sign off because I think I'm

494

00:23:47,600 --> 00:23:46,049

done for now so if anybody sat through