/INFOMOV/

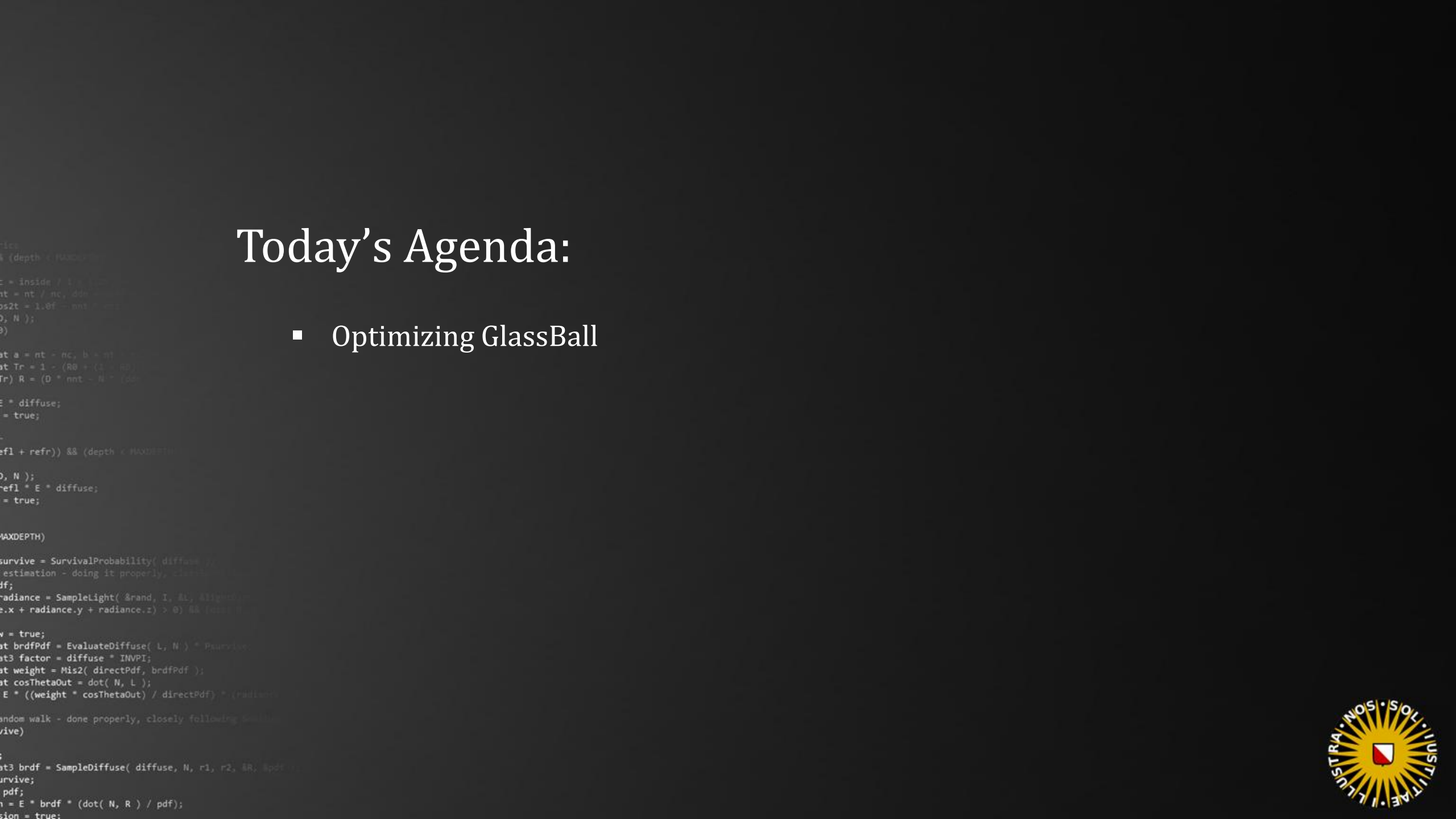
Optimization & Vectorization

J. Bikker - Sep-Nov 2015 - Lecture 4: “Low Level (2)”

Welcome!

Today’s Agenda:

- Optimizing GlassBall



Rules of Engagement

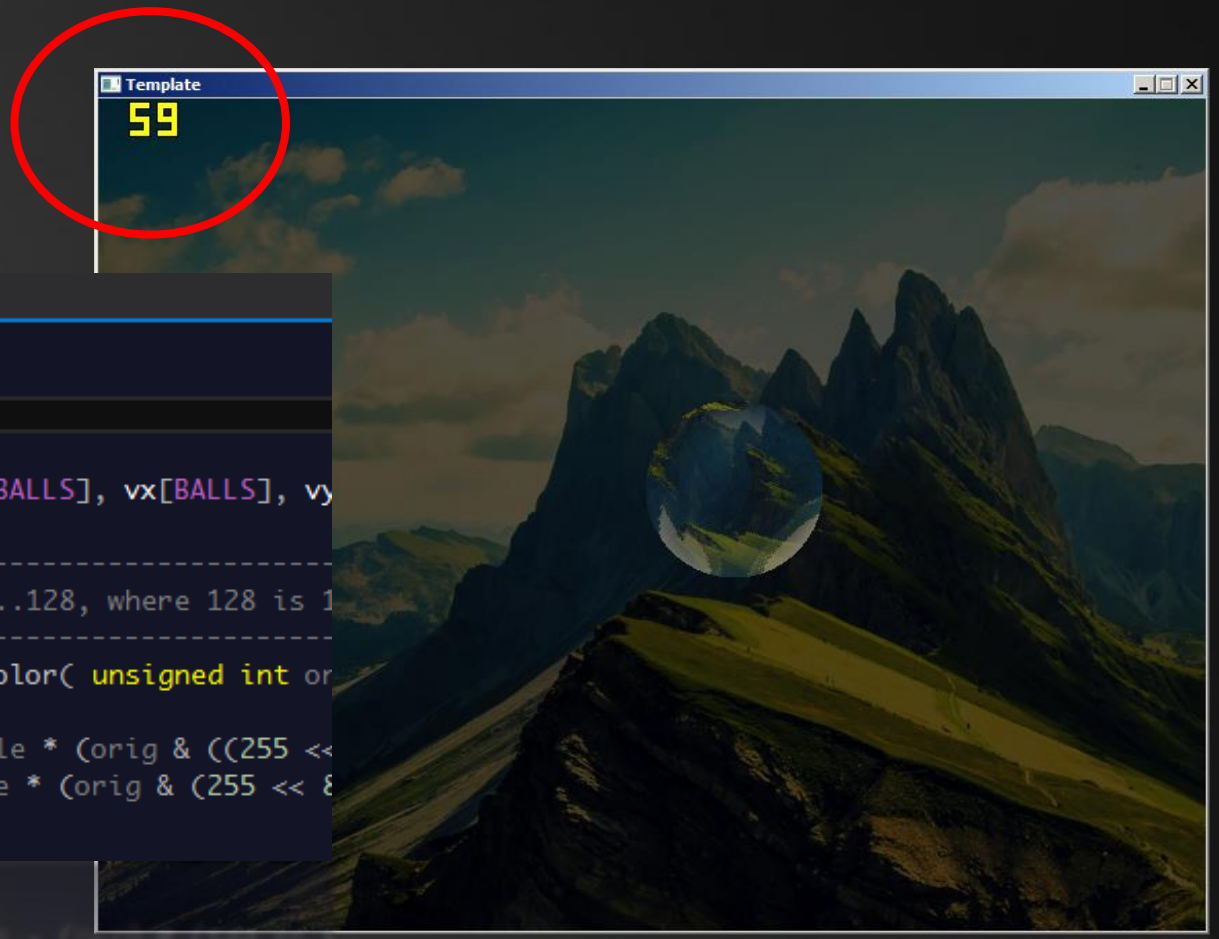
Common Opportunities in Low-level Optimization

1. Avoid Costly Operations
2. Precalculate
3. Pick the Right Data Type
4. Avoid Conditional Branches
5. Early Out
6. Use the Power of Two
7. Do Things Simultaneously

Consistent Approach

(0.) Determine optimization requirements
1. Profile: determine hotspots
2. Analyze hotspots: determine scalability
3. Apply high level optimizations to hotspots
4. Profile again.
5. Parallelize
6. Use GPGPU
7. Profile again.
8. Apply low level optimizations to hotspots
9. Repeat steps 7 and 8 until time runs out
10. Report.

Gathering Intel



game.cpp

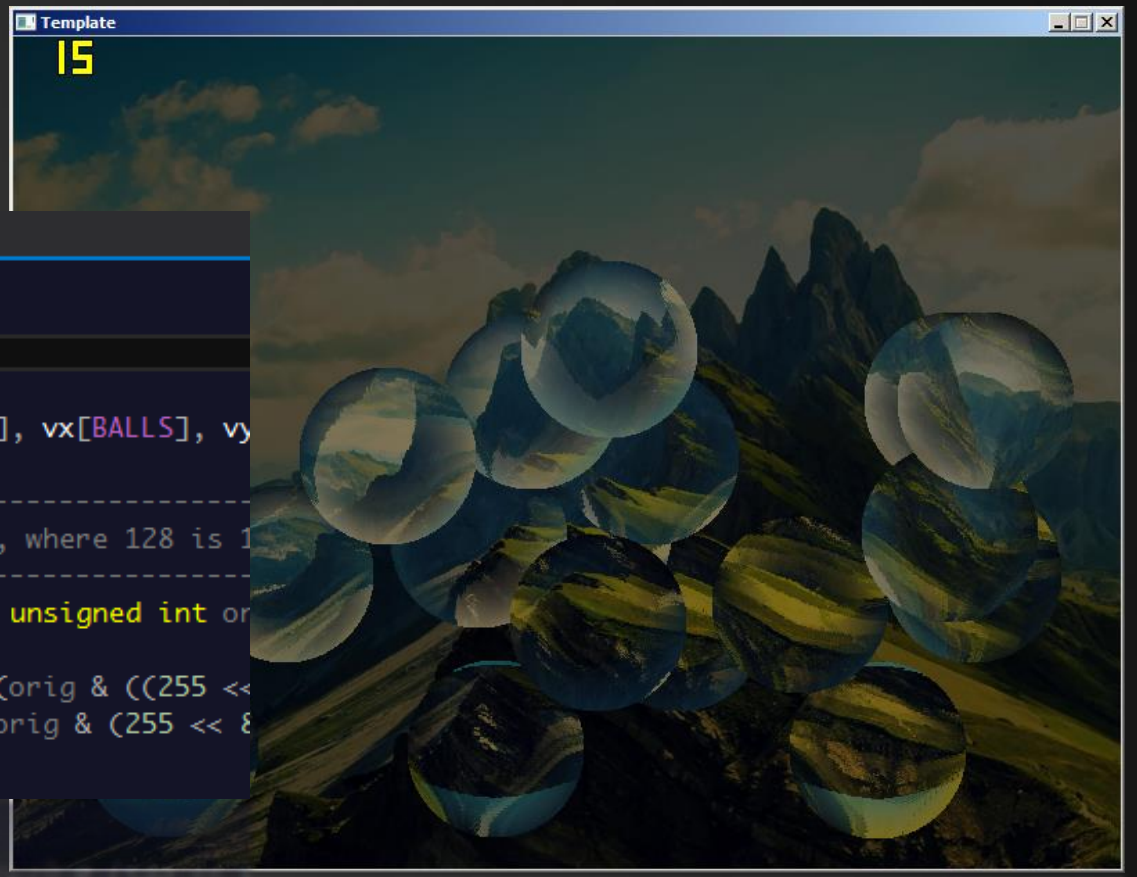
```
#include "template.h"

#define BALLS   2

float ballx[BALLS], bally[BALLS], vx[BALLS], vy

// ----------------------------------------
// Scale a color (range: 0..128, where 128 is 1
// ----------------------------------------
inline unsigned int ScaleColor( unsigned int or
{
    const Pixel rb = ((scale * (orig & ((255 <<
    const Pixel g = ((scale * (orig & (255 << 8
    return (Pixel)rb + g;
}
```

Gathering Intel



game.cpp

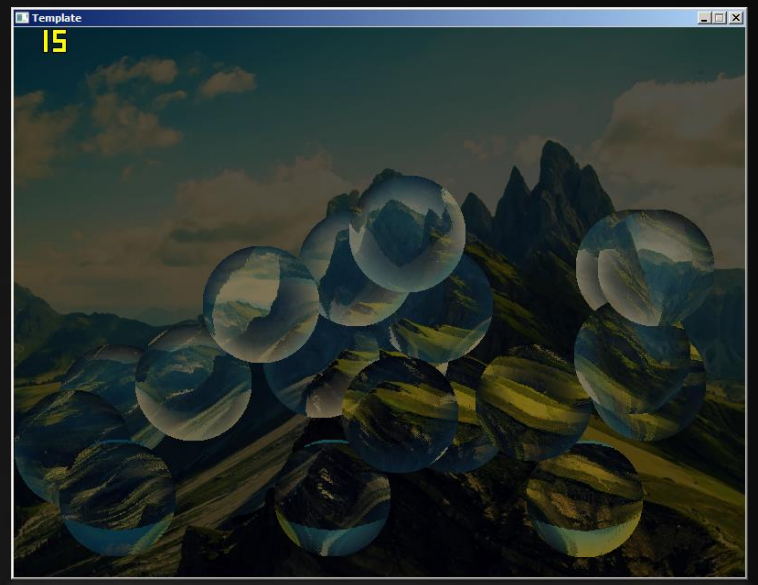
```
#include "template.h"

#define BALLS 20

float ballx[BALLS], bally[BALLS], vx[BALLS], vy

// ----------------------------------------
// Scale a color (range: 0..128, where 128 is 1
// ----------------------------------------
inline unsigned int ScaleColor( unsigned int or
{
    const Pixel rb = ((scale * (orig & ((255 <<
    const Pixel g = ((scale * (orig & (255 << 8
    return (Pixel)rb + g;
}
```

Gathering Intel



Tool 1:

VerySleepy™

(will tell us relative cost of parts of the code)

Tool 2:

Custom timer

(will tell us absolute cost of large tasks)

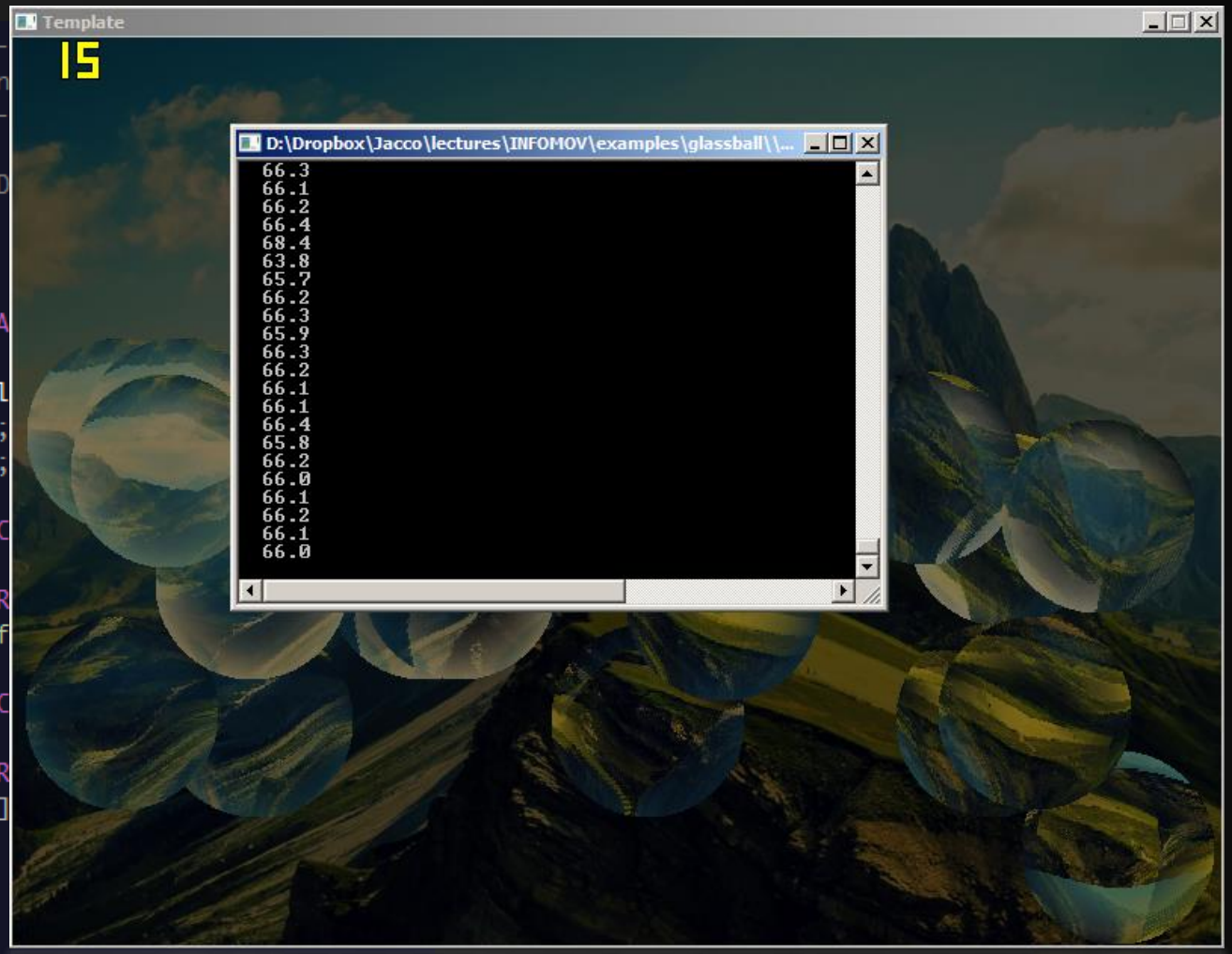
Tool 3:

Running the app with various workloads

(to measure scalability)

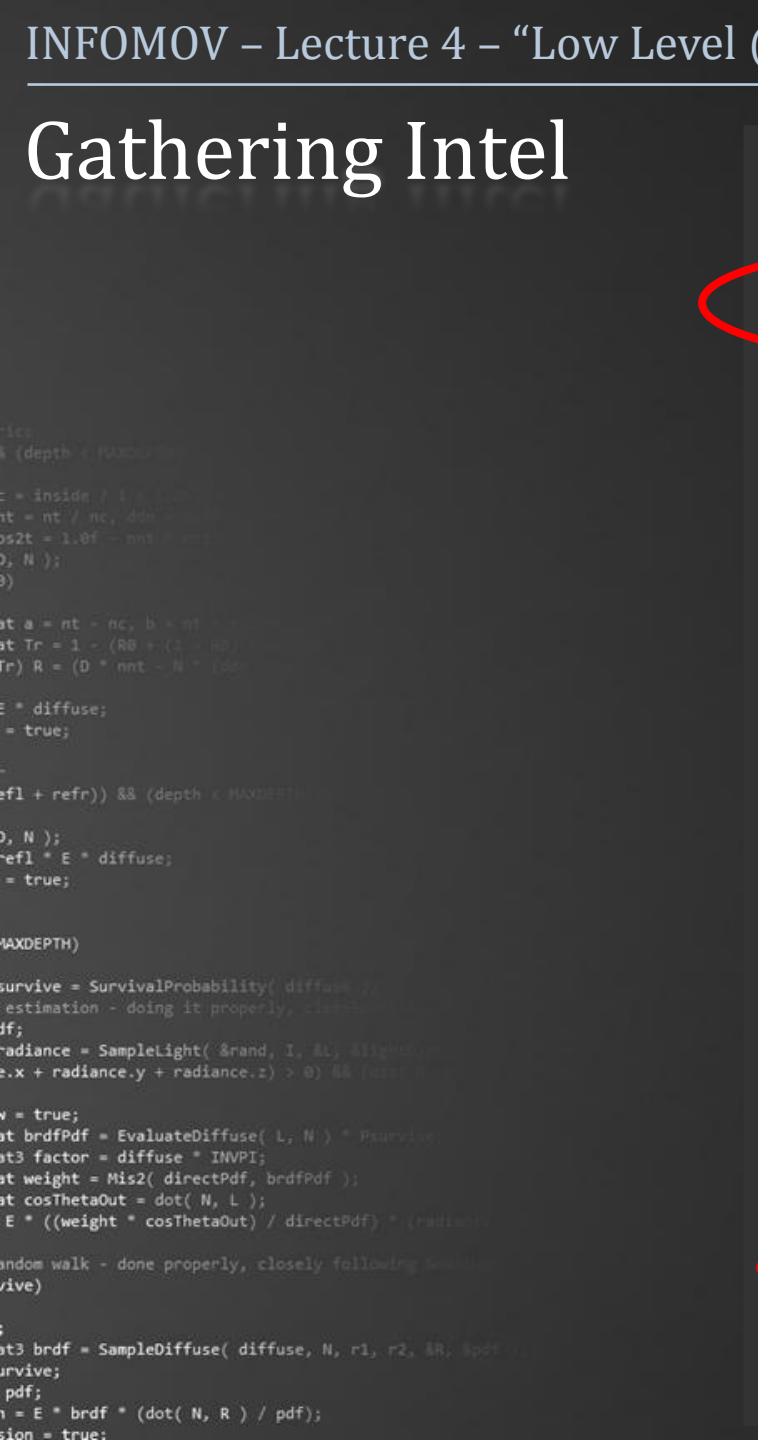
Gathering Intel

```
// -----------------------
// Main game tick function
// -----------------------
timer t;
void Game::Tick( float a_D
{
    screen->Clear( 0 );
    DrawBackdrop();
    for( int i = 0; i < BA
    {
        DrawBall( (int)bal
        bally[i] += vy[i];
        ballx[i] += vx[i];
        vy[i] += 0.2f;
        if (bally[i] > (SC
        {
            bally[i] = SCR
            vy[i] = -0.96f
        }
        if (ballx[i] > (SC
        {
            ballx[i] = SCR
            vx[i] = -vx[i]
        }
        if (ballx[i] < 0)
        {
            ballx[i] = 0;
            vx[i] = -vx[i];
        }
    }
    printf( "%6.1f\n", t.elapsed() );
    t.reset();
}
```

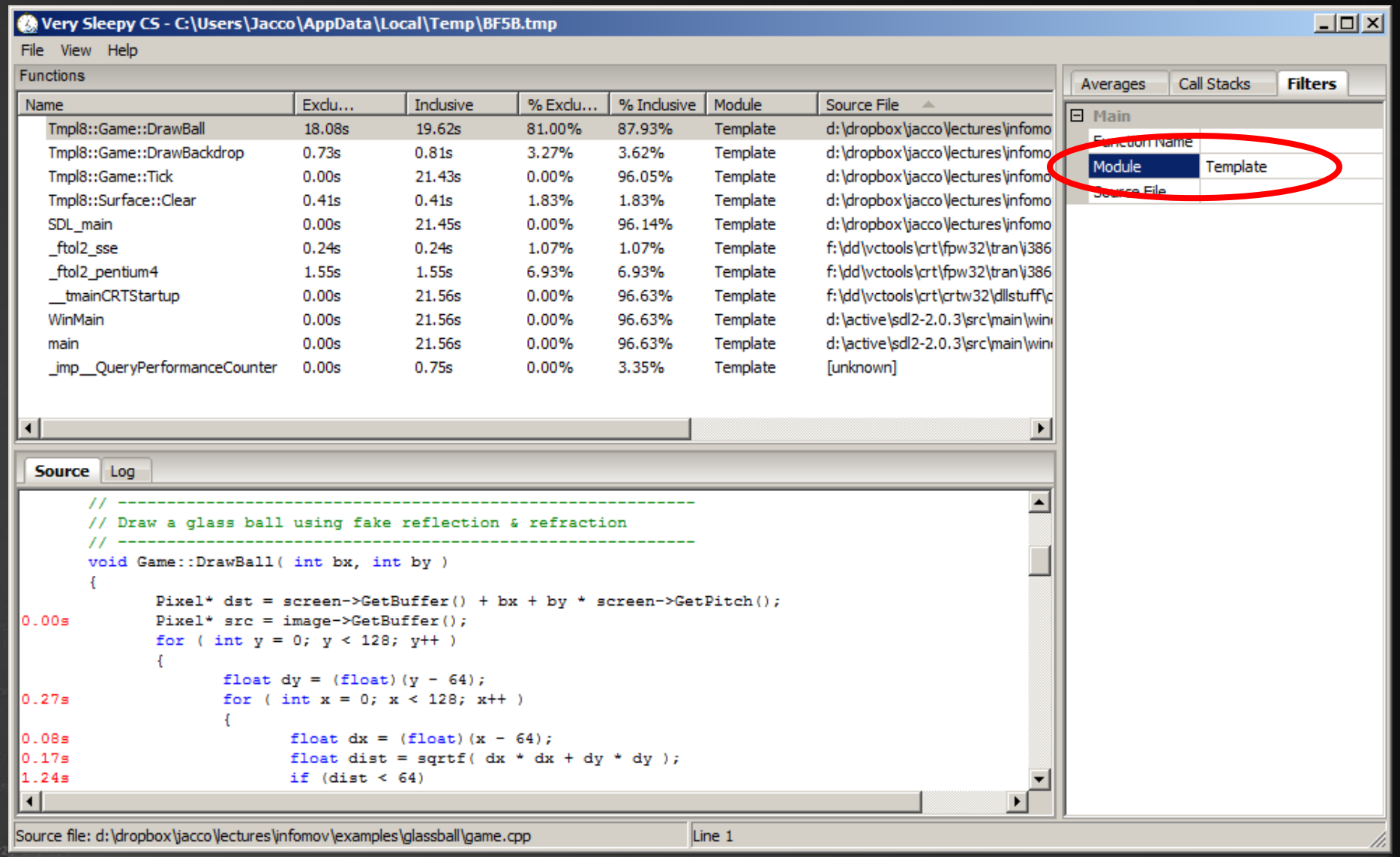


Gathering Intel

```
// -----------------------------------------------------------
// Main game tick function
// -----------------------------------------------------------
timer t;
float smoothed = 60;
bool firstFrame = true;
void Game::Tick( float a_DT )
{
    screen->Clear( 0 );
    DrawBackdrop();
    for( int i = 0; i < BALLS; i++ )
    {
        DrawBall( (int)ballx[i], (int)bally[i] );
        bally[i] += vy[i];
        ballx[i] += vx[i];
        vy[i] += 0.2f;
        if (bally[i] > (SCRHEIGHT - 128))
        {
            bally[i] = SCRHEIGHT - 128;
            vy[i] = -0.96f * vy[i];
        }
        if (ballx[i] > (SCRWIDTH - 128))
        {
            ballx[i] = SCRWIDTH - 128;
            vx[i] = -vx[i];
        }
        if (ballx[i] < 0)
        {
            ballx[i] = 0;
            vx[i] = -vx[i];
        }
    }
    if (!firstFrame) smoothed = 0.95f * smoothed + 0.05f * t.elapsed();
    firstFrame = false;
    printf( "%6.1f\n", smoothed );
    t.reset();
}
```



Gathering Intel



Assess

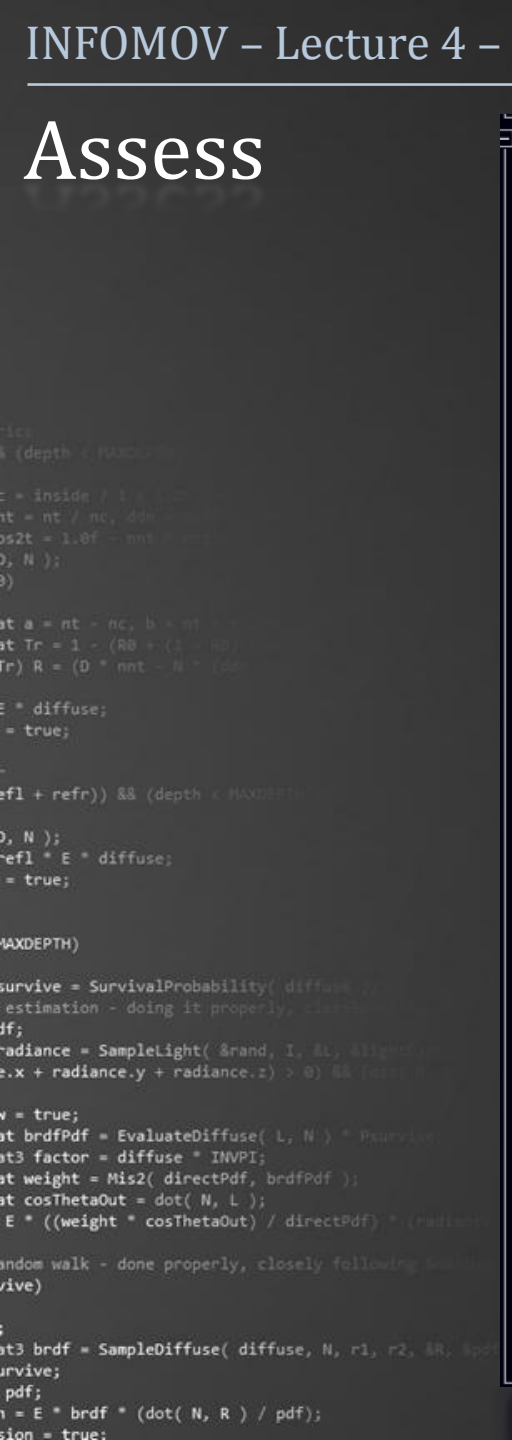
Optimization targets:

1. DrawBall
2. DrawBackdrop
3. Surface::Clear

1. Avoid Costly Operations
2. Precalculate
3. Pick the Right Data Type
4. Avoid Conditional Branches
5. Early Out
6. Use the Power of Two
7. Do Things Simultaneously

Assess

```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    Pixel* src = image->GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        float dy = (float)(y - 64);
        for ( int x = 0; x < 128; x++ )
        {
            float dx = (float)(x - 64);
            float dist = sqrtf( dx * dx + dy * dy );
            if (dist < 64)
            {
                int xoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(x - 50) ) );
                int yoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(y - 50) ) );
                int u1 = ((bx + x) - 4 * xoffs) % SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) % SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) % SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) % SCRHEIGHT;
                Pixel refl = src[max( 0, u1 ) + max( 0, v1 ) * image->GetWidth()];
                Pixel refr = src[max( 0, u2 ) + max( 0, v2 ) * image->GetWidth()];
                int reflscale = (int)(63.0f - 0.015f * (1 - dist) * (1 - dist));
                int refrscale = (int)(0.015f * (1 - dist) * (1 - dist));
                Pixel color1 = ScaleColor( refl, 63 - reflscale );
                Pixel color2 = ScaleColor( refr, 63 - refrscale );
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000) );
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00) );
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff) );
                dst[x + y * screen->GetPitch()] = red + grn + blu;
            }
        }
    }
}
```



Assess

Costly operations:

- sinf, cosf
- sqrt
- %

Precalculation opportunities:

- xoffs, yoffs, dist
- reflscale, refrscale

Data type issues:

- float, int, unsigned int

Conditional branches:

- for loops, dist check, max

Early out:

- it’s a circle (so: convex)

Use the power of 2:

- already happening

Do things simultaneously:

- ?

1. Avoid Costly Operations
2. Precalculate
3. Pick the Right Data Type
4. Avoid Conditional Branches
5. Early Out
6. Use the Power of Two
7. Do Things Simultaneously

Practical

PART 1

- Basics -

Practical


```
24.5
24.3
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24.5
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24.5
24.3
24.5
24.3
```

```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    Pixel* src = image->GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        float dy = (float)(y - 64);
        for ( int x = 0; x < 128; x++ )
        {
            float dx = (float)(x - 64);
            float dist = sqrtf( dx * dx + dy * dy );
            if (dist < 64)
            {
                int xoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(x - 50) ) );
                int yoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(y - 50) ) );
                int u1 = ((bx + x) - 4 * xoffs) % SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) % SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) % SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) % SCRHEIGHT;
                Pixel refl = src[max( 0, u1 ) + max( 0, v1 ) * image->GetWidth()];
                Pixel refr = src[max( 0, u2 ) + max( 0, v2 ) * image->GetWidth()];
                int reflscale = (int)(63.0f - 0.015f * (1 - dist) * (1 - dist));
                int refrscale = (int)(0.015f * (1 - dist) * (1 - dist));
                Pixel color1 = ScaleColor( refl, 63 - reflscale );
                Pixel color2 = ScaleColor( refr, 63 - refrscale );
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xf
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x0
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0
                dst[x + y * screen->GetPitch()] = red + grn + blu;
            }
        }
    }
}
```

```
float dist = dx * dx + dy * dy;
if (dist < (64 * 64))
{
    dist = sqrtf( dist );
```

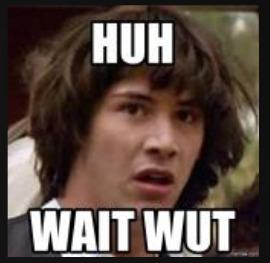
```
float dist = dtab[x][y];
if (dist < 64)
{
```

```
float dist = dtab[y][x];
if (dist < 64)
{
    int xoffs = xotab[y][x];
    int yoffs = yotab[y][x];
```

```
// -----------------------------------------------------------
// Initialize the game
// -----------------------------------------------------------
void Game::Init()
{
    image = new Surface( "testdata/mountains.png" );
    for( int i = 0; i < BALLS; i++ )
    {
        ballx[i] = 100 + Rand( 500 );
        bally[i] = 200 - Rand( 150 );
        vx[i] = (Rand( 1.0f ) > 0.5f) ? 1.6f : -1.6f;
        vy[i] = 0;
    }
    for( int x = 0; x < 128; x++ ) for( int y = 0; y < 128; y++ )
    {
        float dy = (float)(y - 64);
        float dx = (float)(x - 64);
        float dist = sqrtf( dx * dx + dy * dy );
        dtab[y][x] = dist;
        xotab[y][x] = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(x - 50) ) );
        yotab[y][x] = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(y - 50) ) );
    }
}
```

Practical

```
24.3
24.5
24.3
24.5
24.3
24.5
24.3
24.5
24.3
24.5
24.3
24.5
24.3
24.6
```




```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    Pixel* src = image->GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        for ( int x = 0; x < 128; x++ )
        {
            float dist = dtab[y][x];
            if (dist < 64)
            {
                int xoffs = xotab[y][x];
                int yoffs = yotab[y][x];
                int u1 = ((bx + x) - 4 * xoffs) % SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) % SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) % SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) % SCRHEIGHT;
                Pixel refl = src[max( 0, u1 ) + max( 0, v1 ) * image->
                Pixel refr = src[max( 0, u2 ) + max( 0, v2 ) * image->
                int reflscale = (int)(63.0f - 0.015f * (1 - dist) * (1
                int refrscale = (int)(0.015f * (1 - dist) * (1 - dist)
                Pixel color1 = ScaleColor( refl, 63 - reflscale );
                Pixel color2 = ScaleColor( refr, 63 - refrscale );
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000)
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00)
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff)
                dst[x + y * screen->GetPitch()] = red + grn + blu;
            }
        }
    }
}
```

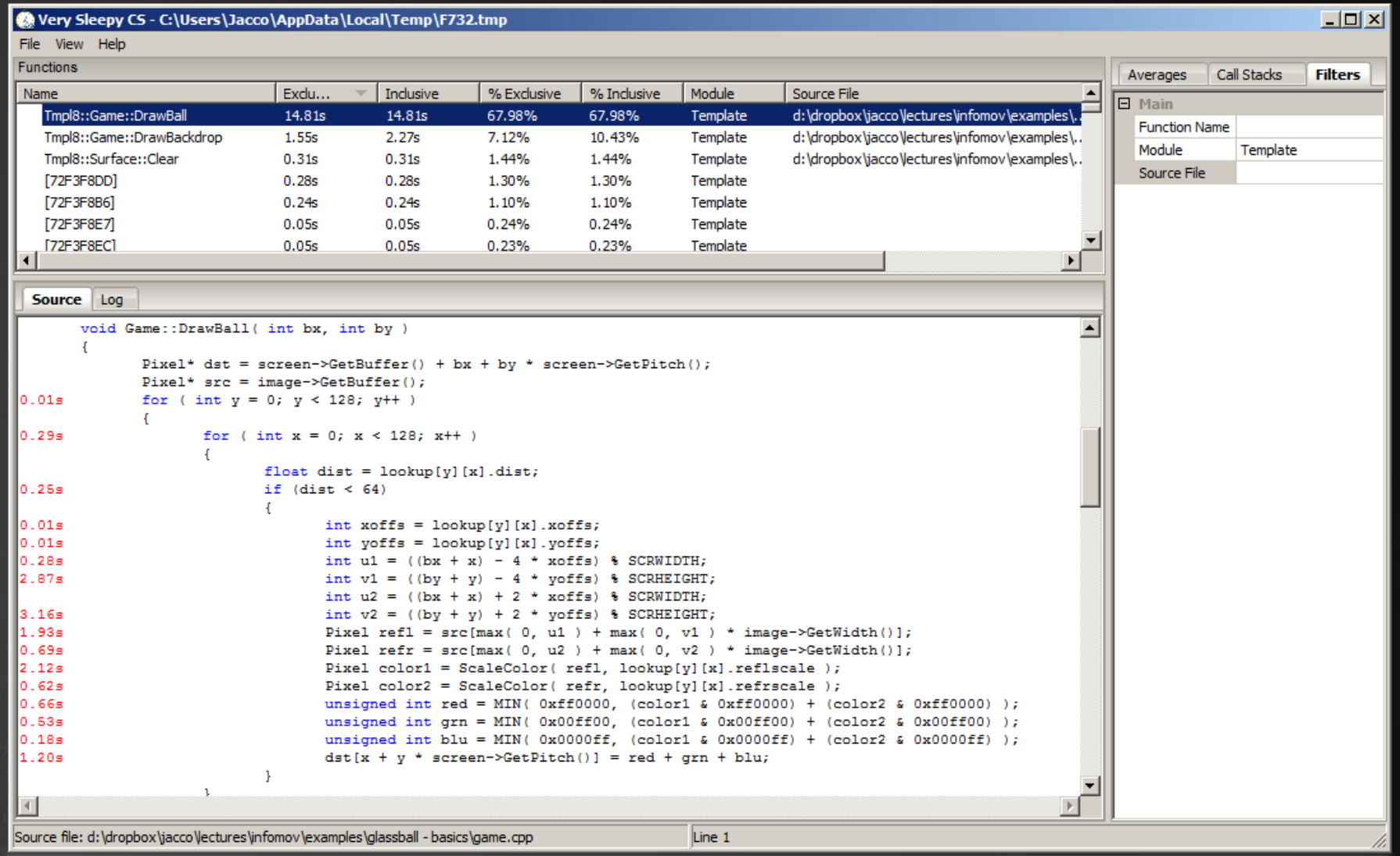
```
struct lookupData
{
    float dist;
    int xoffs;
    int yoffs;
    int reflscale;
    int refrscale;
};
```

$5 * 4 * 128 * 128 = 320\text{Kb}$

```
for( int x = 0; x < 128; x++ ) for( int y = 0; y < 128; y++ )
{
    float dy = (float)(y - 64);
    float dx = (float)(x - 64);
    float dist = sqrtf( dx * dx + dy * dy );
    lookup[y][x].dist = dist;
    lookup[y][x].xoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(x - 50) ) );
    lookup[y][x].yoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(y - 50) ) );
    lookup[y][x].reflscale = 63 - (int)(63.0f - 0.015f * (1 - dist) * (1 - dist));
    lookup[y][x].refrscale = 63 - (int)(0.015f * (1 - dist) * (1 - dist));
}
```

```
dtab[y][x] = dist;
xotab[y][x] = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(x - 50) ) );
yotab[y][x] = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(y - 50) ) );
refltab[y][x] = (int)(63.0f - 0.015f * (1 - dist) * (1 - dist));
refrtab[y][x] = (int)(0.015f * (1 - dist) * (1 - dist));
```

Practical


Very Sleepy CS - C:\Users\Jacco\AppData\Local\Temp\F732.tmp
File View Help
Functions
Name | Exclu... | Inclusive | % Exclusive | % Inclusive | Module | Source File
Tmpl8::Game::DrawBall | 14.81s | 14.81s | 67.98% | 67.98% | Template | d:\dropbox\jacco\lectures\infomov\examples\..
Tmpl8::Game::DrawBackdrop | 1.55s | 2.27s | 7.12% | 10.43% | Template | d:\dropbox\jacco\lectures\infomov\examples\..
Tmpl8::Surface::Clear | 0.31s | 0.31s | 1.44% | 1.44% | Template | d:\dropbox\jacco\lectures\infomov\examples\..
[72F3F8DD] | 0.28s | 0.28s | 1.30% | 1.30% | Template
[72F3F8B6] | 0.24s | 0.24s | 1.10% | 1.10% | Template
[72F3F8E7] | 0.05s | 0.05s | 0.24% | 0.24% | Template
[72F3F8EC] | 0.05s | 0.05s | 0.23% | 0.23% | Template
Averages Call Stacks Filters
Main
Function Name
Module Template
Source File
Source Log
void Game::DrawBall(int bx, int by)
{
Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
Pixel* src = image->GetBuffer();
0.01s for (int y = 0; y < 128; y++)
{
0.29s for (int x = 0; x < 128; x++)
{
float dist = lookup[y][x].dist;
0.25s if (dist < 64)
{
0.01s int xoffs = lookup[y][x].xoffs;
0.01s int yoffs = lookup[y][x].yoffs;
0.28s int u1 = ((bx + x) - 4 * xoffs) % SCRWIDTH;
2.87s int v1 = ((by + y) - 4 * yoffs) % SCRHEIGHT;
int u2 = ((bx + x) + 2 * xoffs) % SCRWIDTH;
3.16s int v2 = ((by + y) + 2 * yoffs) % SCRHEIGHT;
1.93s Pixel refl = src[max(0, u1) + max(0, v1) * image->GetWidth()];
0.69s Pixel refr = src[max(0, u2) + max(0, v2) * image->GetWidth()];
2.12s Pixel color1 = ScaleColor(refl, lookup[y][x].reflscale);
0.62s Pixel color2 = ScaleColor(refr, lookup[y][x].refrscale);
0.66s unsigned int red = MIN(0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000));
0.53s unsigned int grn = MIN(0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00));
0.18s unsigned int blu = MIN(0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff));
1.20s dst[x + y * screen->GetPitch()] = red + grn + blu;
}
Source file: d:\dropbox\jacco\lectures\infomov\examples\glassball - basics\game.cpp
Line 1

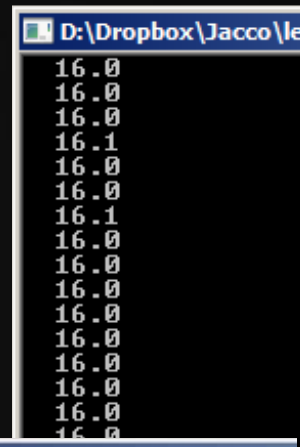
Practical

```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    Pixel* src = image->GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        for ( int x = 0; x < 128; x++ )
        {
            float dist = lookup[y][x].dist;
            if (dist < 64)
            {
                int xoffs = lookup[y][x].xoffs;
                int yoffs = lookup[y][x].yoffs;
                int u1 = ((bx + x) - 4 * xoffs) % SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) % SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) % SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) % SCRHEIGHT;
                Pixel refl = src[max( 0, u1 ) + max( 0, v1 ) * image->GetWidth()];
                Pixel refr = src[max( 0, u2 ) + max( 0, v2 ) * image->GetWidth()];
                Pixel color1 = ScaleColor( refl, lookup[y][x].reflscale );
                Pixel color2 = ScaleColor( refr, lookup[y][x].refrscale );
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000) );
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00) );
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff) );
                dst[x + y * screen->GetPitch()] = red + grn + blu;
            }
        }
    }
}
```

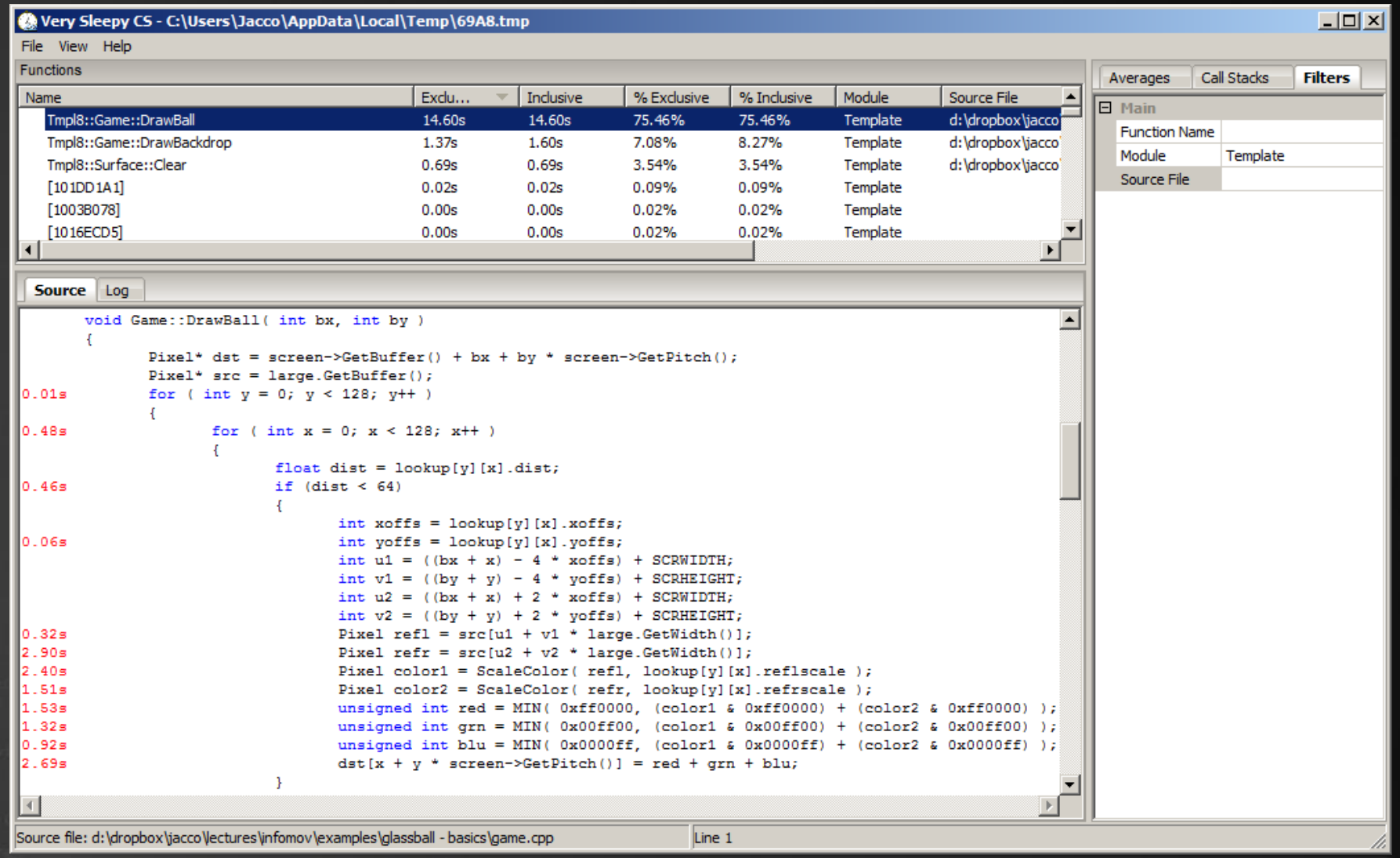
```
Surface large( SCRWIDTH * 3, SCRHEIGHT * 3 );
```

```
void Game::Init()
{
    image = new Surface( "testdata/mountains.png" );
    for( int x = 0; x < 3; x++ ) for( int y = 0; y < 3; y++ )
        image->CopyTo( &large, x * SCRWIDTH, y * SCRHEIGHT );
```

```
int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
Pixel refl = src[u1 + v1 * large.GetWidth()];
Pixel refr = src[u2 + v2 * large.GetWidth()];
```



Practical

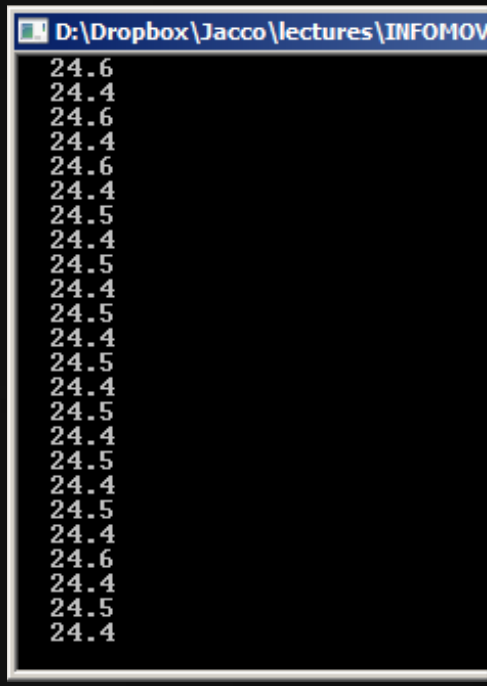

Very Sleepy CS - C:\Users\Jacco\AppData\Local\Temp\69A8.tmp
File View Help
Functions
Name | Exclu... | Inclusive | % Exclusive | % Inclusive | Module | Source File
Tmpl8::Game::DrawBall | 14.60s | 14.60s | 75.46% | 75.46% | Template | d:\dropbox\jacco
Tmpl8::Game::DrawBackdrop | 1.37s | 1.60s | 7.08% | 8.27% | Template | d:\dropbox\jacco
Tmpl8::Surface::Clear | 0.69s | 0.69s | 3.54% | 3.54% | Template | d:\dropbox\jacco
[101DD1A1] | 0.02s | 0.02s | 0.09% | 0.09% | Template
[1003B078] | 0.00s | 0.00s | 0.02% | 0.02% | Template
[1016ECD5] | 0.00s | 0.00s | 0.02% | 0.02% | Template
Averages Call Stacks Filters
Main
Function Name
Module Template
Source File
Source Log
void Game::DrawBall(int bx, int by)
{
Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
Pixel* src = large.GetBuffer();
0.01s for (int y = 0; y < 128; y++)
{
0.48s for (int x = 0; x < 128; x++)
{
float dist = lookup[y][x].dist;
0.46s if (dist < 64)
{
int xoffs = lookup[y][x].xoffs;
0.06s int yoffs = lookup[y][x].yoffs;
int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
0.32s Pixel refl = src[u1 + v1 * large.GetWidth()];
2.90s Pixel refr = src[u2 + v2 * large.GetWidth()];
2.40s Pixel color1 = ScaleColor(refl, lookup[y][x].reflscale);
1.51s Pixel color2 = ScaleColor(refr, lookup[y][x].refrscale);
1.53s unsigned int red = MIN(0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000));
1.32s unsigned int grn = MIN(0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00));
0.92s unsigned int blu = MIN(0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff));
2.69s dst[x + y * screen->GetPitch()] = red + grn + blu;
}
Source file: d:\dropbox\jacco\lectures\infomov\examples\glassball - basics\game.cpp
Line 1

Practical

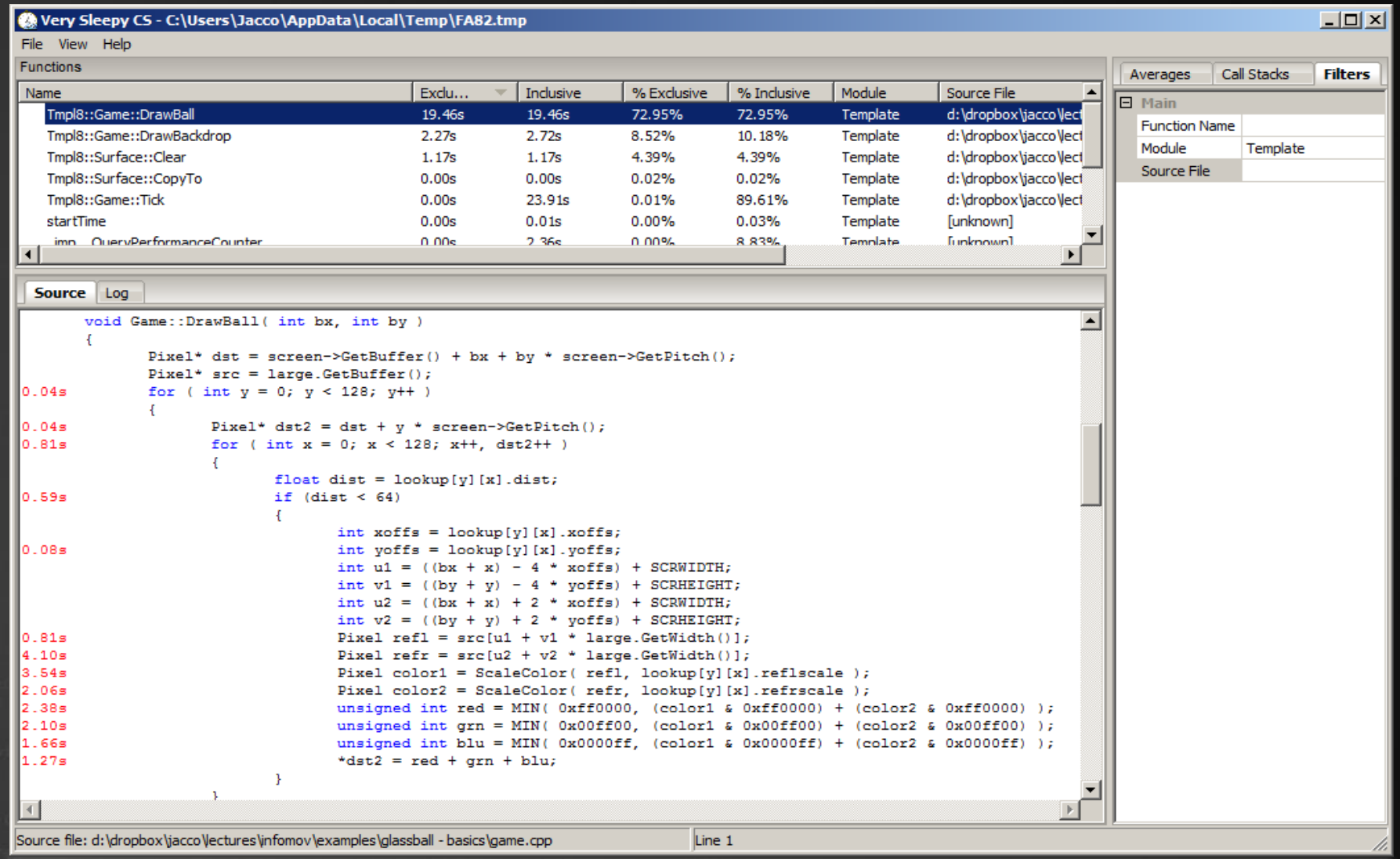
```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    Pixel* src = large.GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        for ( int x = 0; x < 128; x++ )
        {
            float dist = lookup[y][x].dist;
            if (dist < 64)
            {
                int xoffs = lookup[y][x].xoffs;
                int yoffs = lookup[y][x].yoffs;
                int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
                Pixel refl = src[u1 + v1 * large.GetWidth()];
                Pixel refr = src[u2 + v2 * large.GetWidth()];
                Pixel color1 = ScaleColor( refl, lookup[y][x].reflscale );
                Pixel color2 = ScaleColor( refr, lookup[y][x].refrscale );
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000) );
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00) );
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff) );
                dst[x + y * screen->GetPitch()] = red + grn + blu;
            }
        }
    }
}
```

```
for ( int y = 0; y < 128; y++ )
{
    Pixel* dst2 = dst + y * screen->GetPitch();
    for ( int x = 0; x < 128; x++, dst2++ )
```

```
*dst2 = red + grn + blu;
```



Practical


Very Sleepy CS - C:\Users\Jacco\AppData\Local\Temp\FA82.tmp
File View Help
Functions
Name | Exclu... | Inclusive | % Exclusive | % Inclusive | Module | Source File
Tmpl8::Game::DrawBall | 19.46s | 19.46s | 72.95% | 72.95% | Template | d:\dropbox\jacco\lect
Tmpl8::Game::DrawBackdrop | 2.27s | 2.72s | 8.52% | 10.18% | Template | d:\dropbox\jacco\lect
Tmpl8::Surface::Clear | 1.17s | 1.17s | 4.39% | 4.39% | Template | d:\dropbox\jacco\lect
Tmpl8::Surface::CopyTo | 0.00s | 0.00s | 0.02% | 0.02% | Template | d:\dropbox\jacco\lect
Tmpl8::Game::Tick | 0.00s | 23.91s | 0.01% | 89.61% | Template | d:\dropbox\jacco\lect
startTime | 0.00s | 0.01s | 0.00% | 0.03% | Template | [unknown]
Averages Call Stacks Filters
Main
Function Name
Module Template
Source File
Source Log
void Game::DrawBall(int bx, int by)
{
Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
Pixel* src = large.GetBuffer();
0.04s for (int y = 0; y < 128; y++)
{
0.04s Pixel* dst2 = dst + y * screen->GetPitch();
0.81s for (int x = 0; x < 128; x++, dst2++)
{
float dist = lookup[y][x].dist;
0.59s if (dist < 64)
{
int xoffs = lookup[y][x].xoffs;
0.08s int yoffs = lookup[y][x].yoffs;
int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
0.81s Pixel refl = src[u1 + v1 * large.GetWidth()];
4.10s Pixel refr = src[u2 + v2 * large.GetWidth()];
3.54s Pixel color1 = ScaleColor(refl, lookup[y][x].reflscale);
2.06s Pixel color2 = ScaleColor(refr, lookup[y][x].refrscale);
2.38s unsigned int red = MIN(0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000));
2.10s unsigned int grn = MIN(0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00));
1.66s unsigned int blu = MIN(0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff));
1.27s *dst2 = red + grn + blu;
}
}
Source file: d:\dropbox\jacco\lectures\infomov\examples\glassball - basics\game.cpp
Line 1

Practical

PART 2

- Advanced -

Practical

Observations:

- We are suffering cache misses – a lot.
- Scaling colors is expensive.

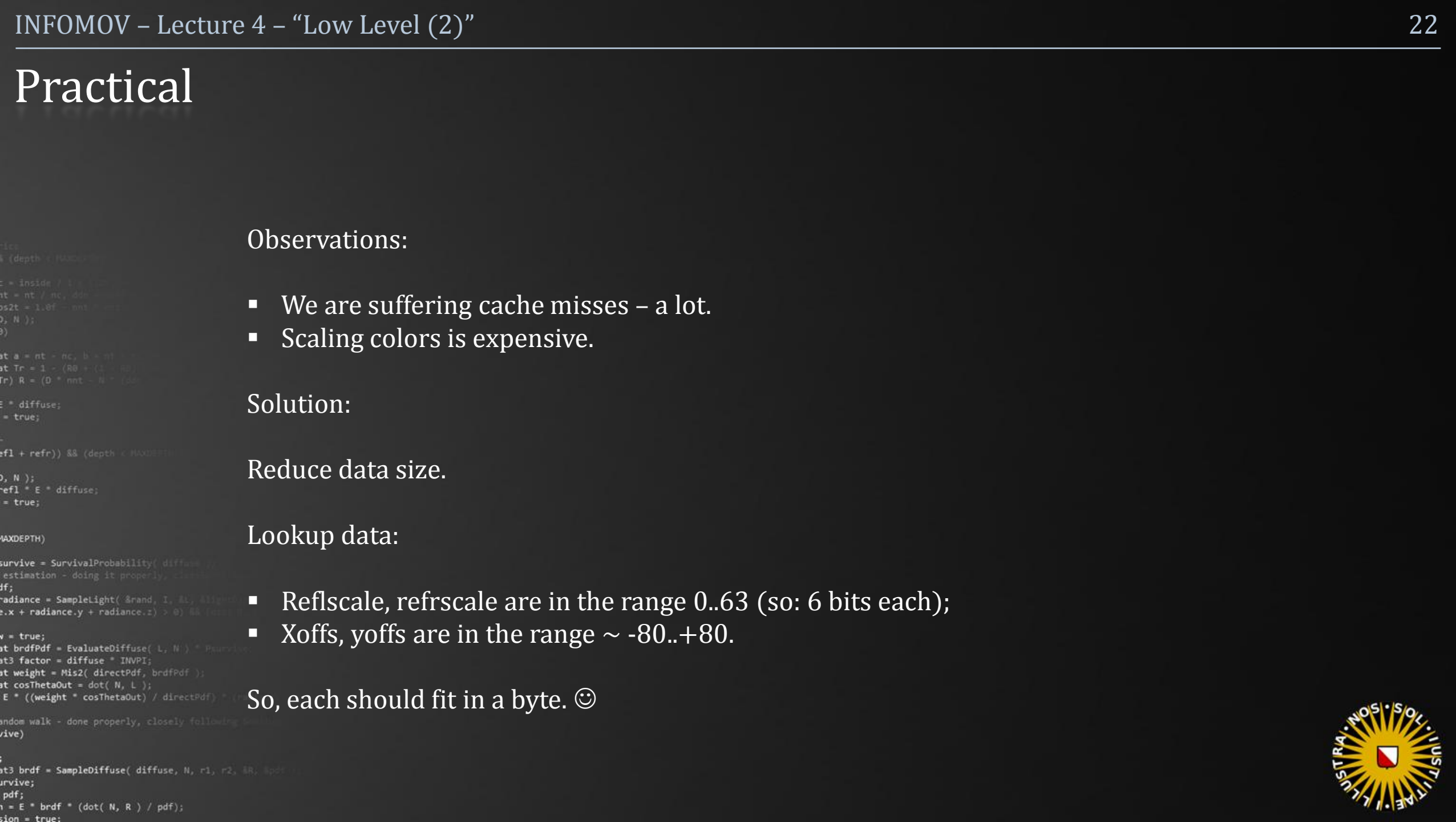
Solution:

Reduce data size.

Lookup data:

- Reflscale, refrscale are in the range 0..63 (so: 6 bits each);
- Xoffs, yoffs are in the range ~ -80..+80.

So, each should fit in a byte. ☺



Practical

```
struct lookupData
{
    float dist;
    unsigned int data;
};
```

```
void Game::Init()
{
    image = new Surface( "testdata/mountains.png" );
    for( int x = 0; x < 3; x++ ) for( int y = 0; y < 3; y++ )
        image->CopyTo( &large, x * SCRWIDTH, y * SCRHEIGHT );
    for( int i = 0; i < BALLS; i++ )
    {
        ballx[i] = 100 + Rand( 500 );
        bally[i] = 200 - Rand( 150 );
        vx[i] = (Rand( 1.0f ) > 0.5f) ? 1.6f : -1.6f;
        vy[i] = 0;
    }
    for( int x = 0; x < 128; x++ ) for( int y = 0; y < 128; y++ )
    {
        float dy = (float)(y - 64);
        float dx = (float)(x - 64);
        float dist = sqrtf( dx * dx + dy * dy );
        lookup[y][x].dist = dist;
        int xoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(x - 50) ) );
        int yoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(y - 50) ) );
        int reflscale = 63 - (int)(63.0f - 0.015f * (1 - dist) * (1 - dist));
        int refrscale = 63 - (int)(0.015f * (1 - dist) * (1 - dist));
        lookup[y][x].data = reflscale + (refrscale << 8) + ((xoffs + 64) << 16) + ((yoffs + 64) << 24);
    }
}
```

```
unsigned int data = lookup[y][x].data;
int xoffs = ((data >> 16) & 255) - 64;
int yoffs = ((data >> 24) & 255) - 64;
int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
Pixel refl = src[u1 + v1 * large.GetWidth()];
Pixel refr = src[u2 + v2 * large.GetWidth()];
Pixel color1 = ScaleColor( refl, data & 255 );
Pixel color2 = ScaleColor( refr, (data >> 8) & 255 );
```

Practical

Observations:

- ~~We are suffering cache misses – a lot.~~
- Scaling colors is expensive.

Solution:

Precalculate scaling.

```
class Surface8
{
public:
    Surface8( char* a_File );
    Surface8( int a_Width, int a_Height );
    ~Surface8();
    unsigned char* GetBuffer() { return m_Buffer; }
    Pixel* GetPalette( int a_Idx ) { return palette[a_Idx]; }
    int GetWidth() { return m_Width; }
    int GetHeight() { return m_Height; }
    void CopyTo( Surface8* a_Dst, int a_X, int a_Y );
    void LoadImage( char* a_File );
    unsigned char* m_Buffer;
    Pixel* palette[PALETTE_LEVELS];
    int m_Width, m_Height, m_Pitch;
};
```

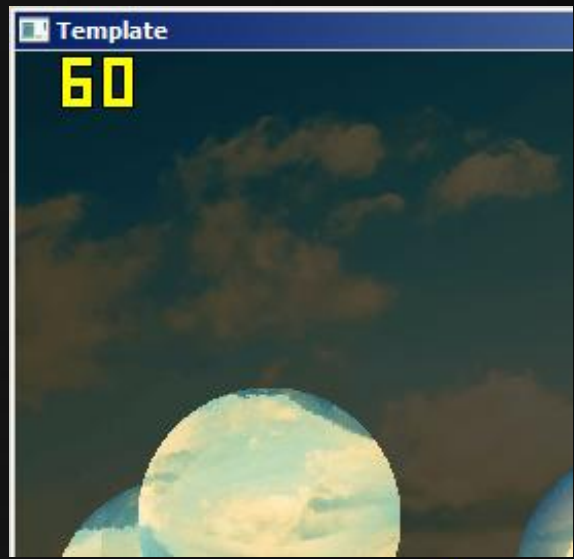
```
void Game::DrawBackdrop()
{
    Pixel* pal = image8->palette[20];
    for( int y = 0; y < SCRHEIGHT; y++ )
    {
        unsigned char* src = image8->GetBuffer() + y * 1024;
        Pixel* dst = screen->GetBuffer() + y * SCRWIDTH;
        for( int x = 0; x < SCRWIDTH; x++ ) *dst++ = pal[*src++];
    }
}
```

```
for( int i = 0; i < PALETTE_LEVELS; i++ )
{
    palette[i] = new Pixel[256];
    for( int j = 0; j < 256; j++ )
    {
        int r = min( 255, (pal[j].rgbRed * i) >> 6 );
        int g = min( 255, (pal[j].rgbGreen * i) >> 6 );
        int b = min( 255, (pal[j].rgbBlue * i) >> 6 );
        palette[i][j] = (r << 16) + (g << 8) + b;
    }
}
```

```
image8 = new Surface8( "testdata/mountains.png" );
for( int x = 0; x < 3; x++ ) for( int y = 0; y < 3; y++ )
    image8->CopyTo( &large8, x * SCRWIDTH, y * SCRHEIGHT );
for( int i = 0; i < PALETTE_LEVELS; i++ ) large8.palette[i] = image8->palette[i];
```

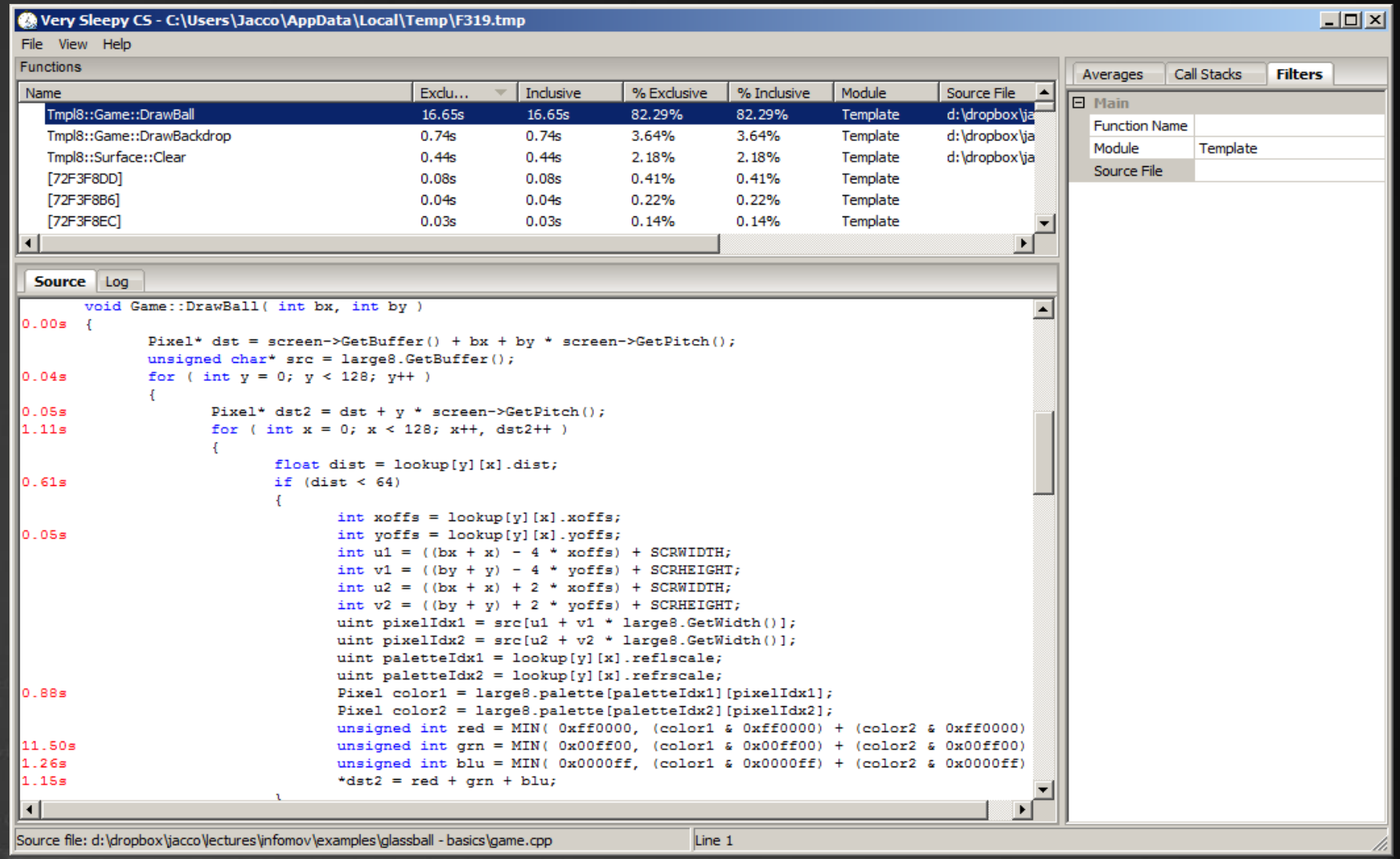
Practical

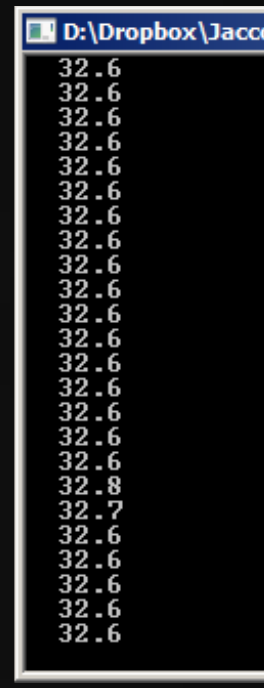
```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    unsigned char* src = large8.GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        Pixel* dst2 = dst + y * screen->GetPitch();
        for ( int x = 0; x < 128; x++, dst2++ )
        {
            float dist = lookup[y][x].dist;
            if (dist < 64)
            {
                int xoffs = lookup[y][x].xoffs;
                int yoffs = lookup[y][x].yoffs;
                int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
                uint pixelIdx1 = src[u1 + v1 * large8.GetWidth()];
                uint pixelIdx2 = src[u2 + v2 * large8.GetWidth()];
                uint paletteIdx1 = lookup[y][x].reflscale;
                uint paletteIdx2 = lookup[y][x].refrscale;
                Pixel color1 = large8.palette[paletteIdx1][pixelIdx1];
                Pixel color2 = large8.palette[paletteIdx2][pixelIdx2];
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000) );
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00) );
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff) );
                *dst2 = red + grn + blu;
            }
        }
    }
}
```



Practical

60





Practical

Observations:

- we now have one expensive line (memory bound);
- and some overhead for the loops and conditionals.

Solution:

Kill one loop; get rid of the conditional.

Practical

```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    unsigned char* src = large8.GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        Pixel* dst2 = dst + y * screen->GetPitch();
        for ( int x = 0; x < 128; x++, dst2++ )
        {
            float dist = lookup[y][x].dist;
            if (dist < 64)
            {
                int xoffs = lookup[y][x].xoffs;
                int yoffs = lookup[y][x].yoffs;
                int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
                uint pixelIdx1 = src[u1 + v1 * large8.GetWidth()];
                uint pixelIdx2 = src[u2 + v2 * large8.GetWidth()];
                uint paletteIdx1 = lookup[y][x].reflscale;
                uint paletteIdx2 = lookup[y][x].refrscale;
                Pixel color1 = large8.palette[paletteIdx1][pixelIdx1];
                Pixel color2 = large8.palette[paletteIdx2][pixelIdx2];
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000) );
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00) );
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff) );
                *dst2 = red + grn + blu;
            }
        }
    }
}
```

What if…

- We precalculate which pixels are inside the ball?

We could store, per pixel:

- ~~x, y~~
- an offset from the top-left corner
- u1, v1, u2, v2 (just add bx, by)

We could drop:

- one loop
- xoffs, yoffs, dist
- The radius test

Let’s do this. ☺

Practical

```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    unsigned char* src = large8.GetBuffer();
    for ( int y = 0; y < 128; y++ )
    {
        Pixel* dst2 = dst + y * screen->GetPitch();
        for ( int x = 0; x < 128; x++, dst2++ )
        {
            float dist = lookup[y][x].dist;
            if (dist < 64)
            {
                int xoffs = lookup[y][x].xoffs;
                int yoffs = lookup[y][x].yoffs;
                int u1 = ((bx + x) - 4 * xoffs) + SCRWIDTH;
                int v1 = ((by + y) - 4 * yoffs) + SCRHEIGHT;
                int u2 = ((bx + x) + 2 * xoffs) + SCRWIDTH;
                int v2 = ((by + y) + 2 * yoffs) + SCRHEIGHT;
                uint pixelIdx1 = src[u1 + v1 * large8.GetWidth()];
                uint pixelIdx2 = src[u2 + v2 * large8.GetWidth()];
                uint paletteIdx1 = lookup[y][x].reflscale;
                uint paletteIdx2 = lookup[y][x].refrscale;
                Pixel color1 = large8.palette[paletteIdx1][pixelIdx1];
                Pixel color2 = large8.palette[paletteIdx2][pixelIdx2];
                unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xff
                unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00
                unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x00
                *dst2 = red + grn + blu;
            }
        }
    }
}
```

```
struct lookupData
{
    int reflscale;
    int refrscale;
    int offset;
    int u1, v1, u2, v2;
};
```

```
for( int x = 0; x < 128; x++ ) for( int y = 0; y < 128; y++ )
{
    float dy = (float)(y - 64);
    float dx = (float)(x - 64);
    float dist = sqrtf( dx * dx + dy * dy );
    if (dist < 64)
    {
        lookup[pixels].offset = x + y * SCRWIDTH;
        int xoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(x - 50) ) );
        int yoffs = (int)((dist / 2 + 10) * sinf( 0.025f * (float)(y - 50) ) );
        lookup[pixels].u1 = (x - 4 * xoffs) + SCRWIDTH;
        lookup[pixels].v1 = (y - 4 * yoffs) + SCRHEIGHT;
        lookup[pixels].u2 = (x + 2 * xoffs) + SCRWIDTH;
        lookup[pixels].v2 = (y + 2 * yoffs) + SCRHEIGHT;
        lookup[pixels].reflscale = 63 - (int)(63.0f - 0.015f * (1 - dist) * (1 - dist));
        lookup[pixels].refrscale = 63 - (int)(0.015f * (1 - dist) * (1 - dist));
        pixels++;
    }
}
```

Practical

```
void Game::DrawBall( int bx, int by )
{
    Pixel* dst = screen->GetBuffer() + bx + by * screen->GetPitch();
    unsigned char* src = large8.GetBuffer();
    for( int i = 0; i < pixels; i++ )
    {
        int u1 = bx + lookup[i].u1;
        int v1 = by + lookup[i].v1;
        int u2 = bx + lookup[i].u2;
        int v2 = by + lookup[i].v2;
        uint pixelIdx1 = src[u1 + v1 * large8.GetWidth()];
        uint pixelIdx2 = src[u2 + v2 * large8.GetWidth()];
        uint paletteIdx1 = lookup[i].reflscale;
        uint paletteIdx2 = lookup[i].refrscale;
        Pixel color1 = large8.palette[paletteIdx1][pixelIdx1];
        Pixel color2 = large8.palette[paletteIdx2][pixelIdx2];
        unsigned int red = MIN( 0xff0000, (color1 & 0xff0000) + (color2 & 0xff0000) );
        unsigned int grn = MIN( 0x00ff00, (color1 & 0x00ff00) + (color2 & 0x00ff00) );
        unsigned int blu = MIN( 0x0000ff, (color1 & 0x0000ff) + (color2 & 0x0000ff) );
        dst[lookup[i].offset] = red + grn + blu;
    }
}
```

```
void Game::DrawBall( int bx, int by )
{
    Pixel*dst=screen->GetBuffer()+bx+by*800;
    unsigned char*src=large8.GetBuffer();
    for(int i=0;i<pixels;i++)
    {
        int u1=bx+lookup[i].u1,v1=by+lookup[i].v1;
        int u2=bx+lookup[i].u2,v2=by+lookup[i].v2;
        uint a=src[u1+v1*large8.GetWidth()];
        uint b=src[u2+v2*large8.GetWidth()];
        uint c=lookup[i].reflscale,d=lookup[i].refrscale;
        Pixel e=large8.palette[c][a],f=large8.palette[d][b];
        uint r=MIN(0xff0000,(e&0xff0000)+(f&0xff0000));
        uint g=MIN(0xff00,(e&0xff00)+(f&0xff00));
        uint x=MIN(255,(e&255)+(f&255));
        dst[lookup[i].offset]=r+g+x;
    }
}
```

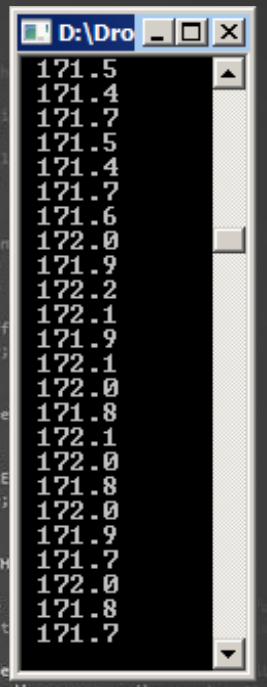
Final steps:

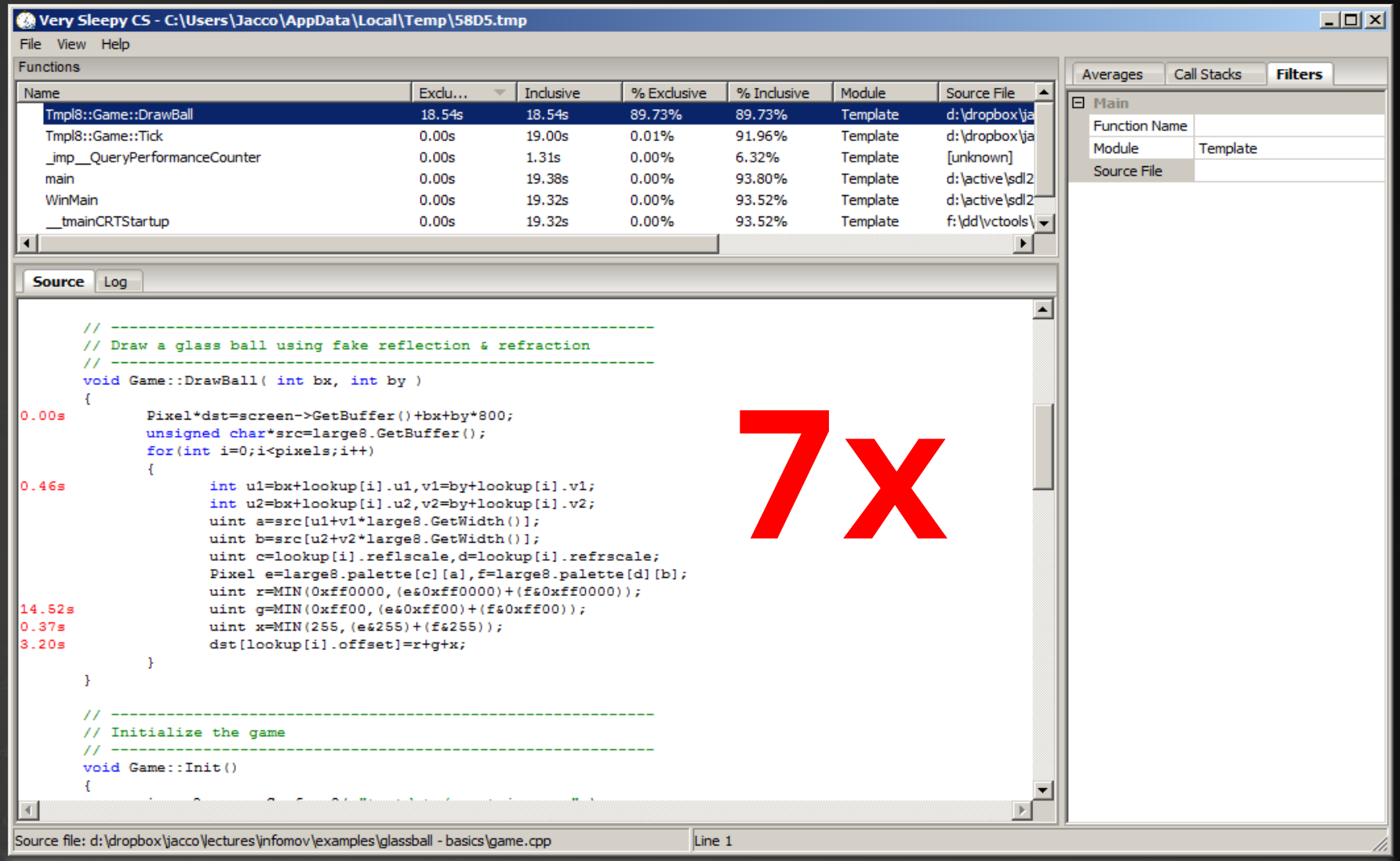
- Remove Clear(0).
- Precalculate scaled backdrop.

Practical

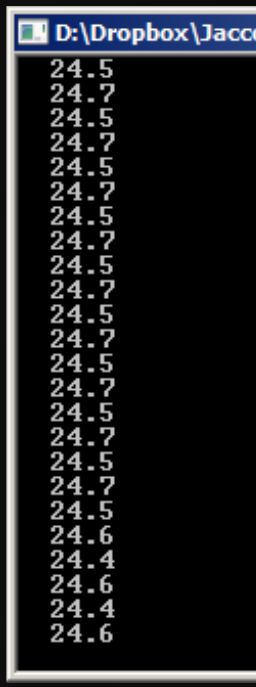
original

optimized





7x



Practical

PART 2

- Insane -

Practical

Observations:

- many pixels are overdrawn…
- there is a big penalty for writing the final pixel.
- everything is running on a single core.
- we are not using the GPU.

/INFOMOV/

END of “Low Level (2)”

next lecture: “caching (2)”