

fractal-channel-hopping

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1 audio/fch.pd

```
#N canvas 3 63 450 524 10;  
#X obj 21 20 table \${0}-notes 24;  
#X obj 21 42 loadbang;  
#X obj 21 86 s \${0}-notes;  
5 #X obj 21 108 loadbang;  
#X msg 21 151 1;  
#X obj 75 197 + 1;  
#X obj 75 219 mod 24;  
#X obj 21 195 f;  
10 #X obj 21 217 t f f;  
#X obj 21 239 mod 4;  
#X obj 21 261 pack f f;  
#X obj 72 241 tabread \${0}-notes;  
#X obj 21 283 route 0 1 2 3;
```

```
15 #X obj 18 464 dac~;
#X obj 277 125 loadbang;
#X msg 277 147 \; pd dsp 1;
#X obj 21 313 voice~;
#X obj 31 333 voice~;
20 #X obj 39 355 voice~;
#X obj 51 373 voice~;
#X obj 18 396 hip~ 10;
#X obj 18 420 lop~ 10000;
#X obj 131 283 route 0 1 2 3;
25 #X obj 131 313 voice~;
#X obj 141 333 voice~;
#X obj 149 355 voice~;
#X obj 161 373 voice~;
#X obj 128 396 hip~ 10;
30 #X obj 128 418 lop~ 10000;
#X msg 21 64 0 0 9 5 2 10 7 3 0 8 5 1 10 6 3 11 8 4 1 9 6 2 11 7 4
;
#X obj 21 173 metro 2500;
#X obj 208 478 writesf~ 2;
35 #X msg 262 260 open -bytes 4 fch.wav \, start;
#X obj 21 130 delay 1000;
#X obj 280 289 delay 1.8e+06;
#X msg 280 345 stop;
#X msg 280 394 \; pd quit;
40 #X obj 293 370 delay 1000;
#X obj 262 211 delay 60000;
#X floatatom 154 213 5 0 0 0 - - -, f 5;
#X connect 1 0 29 0;
#X connect 3 0 33 0;
45 #X connect 4 0 30 0;
#X connect 5 0 6 0;
#X connect 6 0 7 1;
#X connect 7 0 5 0;
#X connect 7 0 8 0;
50 #X connect 7 0 39 0;
#X connect 8 0 9 0;
#X connect 8 1 11 0;
#X connect 9 0 10 0;
#X connect 10 0 12 0;
55 #X connect 10 0 22 0;
#X connect 11 0 10 1;
#X connect 12 0 16 0;
#X connect 12 1 17 0;
#X connect 12 2 18 0;
60 #X connect 12 3 19 0;
#X connect 14 0 15 0;
#X connect 16 0 20 0;
#X connect 17 0 20 0;
#X connect 18 0 20 0;
65 #X connect 19 0 20 0;
#X connect 20 0 21 0;
#X connect 21 0 13 0;
#X connect 21 0 31 0;
#X connect 22 0 23 0;
70 #X connect 22 1 24 0;
#X connect 22 2 25 0;
```

```
#X connect 22 3 26 0;
#X connect 23 0 27 0;
#X connect 24 0 27 0;
75 #X connect 25 0 27 0;
#X connect 26 0 27 0;
#X connect 27 0 28 0;
#X connect 28 0 13 1;
#X connect 28 0 31 1;
80 #X connect 29 0 2 0;
#X connect 30 0 7 0;
#X connect 32 0 31 0;
#X connect 33 0 4 0;
#X connect 33 0 38 0;
85 #X connect 34 0 35 0;
#X connect 34 0 37 0;
#X connect 35 0 31 0;
#X connect 37 0 36 0;
#X connect 38 0 32 0;
90 #X connect 38 0 34 0;
```

2 audio/voice~.pd

```
#N canvas 3 58 450 300 10;
#X obj 174 19 inlet;
#X obj 174 41 mtof;
#X obj 30 33 noise~;
5 #X obj 83 64 vcf~ 50;
#X obj 19 286 outlet~;
#X obj 83 84 vcf~ 50;
#X obj 83 104 vcf~ 50;
#X obj 83 124 vcf~ 50;
10 #X obj 83 144 vcf~ 50;
#X obj 83 164 vcf~ 50;
#X obj 83 184 vcf~ 50;
#X obj 83 205 vcf~ 50;
#X obj 83 225 vcf~ 50;
15 #X obj 83 245 vcf~ 50;
#X obj 83 265 vcf~ 50;
#X obj 174 63 * 2;
#X obj 174 85 * 2;
#X obj 174 107 * 2;
20 #X obj 174 129 * 2;
#X obj 174 151 * 2;
#X obj 174 173 * 2;
#X obj 174 195 * 2;
#X obj 174 217 * 2;
25 #X obj 174 239 * 2;
#X obj 174 261 * 2;
#X connect 0 0 1 0;
#X connect 1 0 3 1;
#X connect 1 0 15 0;
30 #X connect 2 0 3 0;
#X connect 2 0 5 0;
#X connect 2 0 6 0;
#X connect 2 0 7 0;
#X connect 2 0 8 0;
35 #X connect 2 0 9 0;
```

```
#X connect 2 0 10 0;
#X connect 2 0 11 0;
#X connect 2 0 12 0;
#X connect 2 0 13 0;
40 #X connect 2 0 14 0;
#X connect 3 0 4 0;
#X connect 5 0 4 0;
#X connect 6 0 4 0;
#X connect 7 0 4 0;
45 #X connect 8 0 4 0;
#X connect 9 0 4 0;
#X connect 10 0 4 0;
#X connect 11 0 4 0;
#X connect 12 0 4 0;
50 #X connect 13 0 4 0;
#X connect 14 0 4 0;
#X connect 15 0 5 1;
#X connect 15 0 16 0;
#X connect 16 0 6 1;
55 #X connect 16 0 17 0;
#X connect 17 0 7 1;
#X connect 17 0 18 0;
#X connect 18 0 8 1;
#X connect 18 0 19 0;
60 #X connect 19 0 9 1;
#X connect 19 0 20 0;
#X connect 20 0 10 1;
#X connect 20 0 21 0;
#X connect 21 0 11 1;
65 #X connect 21 0 22 0;
#X connect 22 0 12 1;
#X connect 22 0 23 0;
#X connect 23 0 13 1;
#X connect 23 0 24 0;
70 #X connect 24 0 14 1;
```

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265 more than your reasonable cost of physically performing this
conveying of source, or (2) access to copy the
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```

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```
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    This program comes with ABSOLUTELY NO WARRANTY; for details type 'show w'.
    This is free software, and you are welcome to redistribute it
    under certain conditions; type 'show c' for details.
```

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4 .gitignore

```
src/fractal-channel-hopping
src/*.frag.c
photo/fractal-photo-mosaic
get-iplayer
5  rtmpdump
   tmp
   *.ogv
   *.m2v
   *.wav
10 *.mp2
   *.mkv
   *.data
   *.mp4
   *.mpeg
15 *.webm
```

5 NEWS

```
v6    play videos from folders
v5    fix for get-iplayer mode name changes
v4    mplayer simplified stuff
v3    graphics speed boost etc
5    v2    preliminary sound mixing
     v1    first publicised version
```

6 photo/fractal-photo-mosaic.c

```

#include <assert.h>
#include <math.h>
#include <stdio.h>
#include <stdlib.h>
5  #include <GL/glew.h>
#include <GLFW/glfw3.h>

#define COUNT (103+1)
#define WIDTH 1920
10 #define HEIGHT 1080

static unsigned char raw[COUNT][HEIGHT][WIDTH][3];
static unsigned char raw16[COUNT][16][16][3];

15 static double lab16[COUNT][16][16][3];
static double lab2[COUNT][2][2][3];

static float graph[COUNT][8][8];

20 static int visited[COUNT];

static unsigned char out[HEIGHT][WIDTH][3];

static const char *vert =
25 "#version 400 core\n"
"uniform vec2 delta;\n"
"uniform float zoom;\n"
"layout(location = 0) in vec2 pos;\n"
"layout(location = 1) in vec2 tc;\n"
30 "out vec2 c;\n"
"void main() {\n"
"    gl_Position = vec4(zoom * (pos - delta) + delta, 0.0, 1.0);\n"
"    c = vec2(tc.x, 1.0 - tc.y);\n"
"}\n"
35 ;

static const char *frag =
"#version 400 core\n"
"uniform sampler2DArray tex;\n"
40 "uniform sampler2DArray map;\n"
"uniform int ix;\n"
"uniform vec3 blend;\n"
"in vec2 c;\n"
"layout(location = 0) out vec3 colour;\n"
45 "void main() {\n"
"    float l = textureQueryLod(tex, c).y;\n"
"    vec3 p0 = vec3(c, float(ix));\n"
"    vec3 p1 = vec3(8.0 * p0.xy, texture(map, p0).x);\n"
"    p1.xy -= floor(p1.xy);\n"
50 "    vec3 p2 = vec3(8.0 * p1.xy, texture(map, p1).x);\n"
"    p2.xy -= floor(p2.xy);\n"
"    vec3 sum = vec3(0.0);\n"
"    sum += textureLod(tex, p0, l).rgb * blend.x;\n"
"    sum += textureLod(tex, p1, l + 3).rgb * blend.y;\n"
55 "    sum += textureLod(tex, p2, l + 6).rgb * blend.z;\n"

```

```

" colour = sum;\n"
"}\n"
;

60 static void debug_program(GLuint program, const char *name) {
    if (program) {
        GLint linked = GL_FALSE;
        glGetProgramiv(program, GL_LINK_STATUS, &linked);
        if (linked != GL_TRUE) {
65             fprintf(stderr, "%s: OpenGL shader program link failed\n", name);
        }
        GLint length = 0;
        glGetProgramiv(program, GL_INFO_LOG_LENGTH, &length);
        char *buffer = (char *) malloc(length + 1);
70         glGetProgramInfoLog(program, length, 0, buffer);
        buffer[length] = 0;
        if (buffer[0]) {
            fprintf(stderr, "%s: OpenGL shader program info log\n", name);
            fprintf(stderr, "%s\n", buffer);
75         }
        free(buffer);
        assert(linked == GL_TRUE);
    } else {
        fprintf(stderr, "%s: OpenGL shader program creation failed\n", name);
80     }
}

static void debug_shader(GLuint shader, GLenum type, const char *name) {
    const char *tname = 0;
85     switch (type) {
        case GL_VERTEX_SHADER:    tname = "vertex";    break;
        case GL_FRAGMENT_SHADER: tname = "fragment"; break;
        case GL_COMPUTE_SHADER:   tname = "compute";  break;
        default:                  tname = "unknown";  break;
90     }
    if (shader) {
        GLint compiled = GL_FALSE;
        glGetShaderiv(shader, GL_COMPILE_STATUS, &compiled);
        if (compiled != GL_TRUE) {
95             fprintf(stderr, "%s: OpenGL %s shader compile failed\n", name, tname);
        }
        GLint length = 0;
        glGetShaderiv(shader, GL_INFO_LOG_LENGTH, &length);
        char *buffer = (char *) malloc(length + 1);
100        glGetShaderInfoLog(shader, length, 0, buffer);
        buffer[length] = 0;
        if (buffer[0]) {
            fprintf(stderr, "%s: OpenGL %s shader info log\n", name, tname);
            fprintf(stderr, "%s\n", buffer);
105        }
        free(buffer);
        assert(compiled == GL_TRUE);
    } else {
        fprintf(stderr, "%s: OpenGL %s shader creation failed\n", name, tname);
110    }
}

```

```

static void compile_shader(GLint program, GLenum type, const char *name, const ↵
    ↵ GLchar *source) {
    GLuint shader = glCreateShader(type);
115   glShaderSource(shader, 1, &source, 0);
    glCompileShader(shader);
    debug_shader(shader, type, name);
    glAttachShader(program, shader);
120   glDeleteShader(shader);
}

static GLint compile_program(const char *name, const GLchar *vert, const GLchar ↵
    ↵ *frag) {
    GLint program = glCreateProgram();
    if (vert) { compile_shader(program, GL_VERTEX_SHADER, name, vert); }
125   if (frag) { compile_shader(program, GL_FRAGMENT_SHADER, name, frag); }
    glLinkProgram(program);
    debug_program(program, name);
    return program;
}
130 static double xyz2lab_f(double t)
{
    static const double e = 0.008856;
    static const double k = 903.3;
    if (t > e)
135     return cbrt(t);
    else
        return (k * t + 16) / 116;
}
static void xyz2lab(double x, double y, double z, double *l, double *a, double *↵
    ↵ b)
140 {
    static const double xn = 0.95047;
    static const double yn = 1.00000;
    static const double zn = 1.08883;
    x /= xn;
145   y /= yn;
    z /= zn;
    x = xyz2lab_f(x);
    y = xyz2lab_f(y);
    z = xyz2lab_f(z);
150   *l = 116 * y - 16;
    *a = 500 * (x - y);
    *b = 200 * (y - z);
}

155 static double srgb2xyz_f(double c)
{
    if (c < 0.04045)
        return c / 12.92;
    else
160     return pow((c + 0.055) / 1.055, 2.4);
}
static void srgb2xyz(double r, double g, double b, double *x, double *y, double ↵
    ↵ *z)
{
    static const double m[3][3] =
165     { { 0.4124, 0.3576, 0.1805 }

```

```

    , { 0.2126, 0.7152, 0.0722 }
    , { 0.0193, 0.1192, 0.9505 }
    };
    r = srgb2xyz_f(r);
170   g = srgb2xyz_f(g);
    b = srgb2xyz_f(b);
    *x = m[0][0] * r + m[0][1] * g + m[0][2] * b;
    *y = m[1][0] * r + m[1][1] * g + m[1][2] * b;
175   *z = m[2][0] * r + m[2][1] * g + m[2][2] * b;
}

static void srgb2lab(double r, double g, double b, double *l, double *a, double *
    ↵ *bb)
{
180   double x, y, z;
    srgb2xyz(r, g, b, &x, &y, &z);
    xyz2lab(x, y, z, l, a, bb);
}

185 extern int main()
{
    srand(0x1cedcafe);

190   FILE *fraw = fopen("image.data", "rb");
    fread(&raw[0][0][0][0], (COUNT-1) * WIDTH * HEIGHT * 3, 1, fraw);
    fclose(fraw);

    fraw = fopen("thumbs.data", "rb");
195   fread(&raw16[0][0][0][0], (COUNT-1) * 16 * 16 * 3, 1, fraw);
    fclose(fraw);

    glfwInit();
    glfwWindowHint(GLFW_CONTEXT_VERSION_MAJOR, 4);
200   glfwWindowHint(GLFW_CONTEXT_VERSION_MINOR, 0);
    glfwWindowHint(GLFW_OPENGL_FORWARD_COMPAT, GL_TRUE);
    glfwWindowHint(GLFW_OPENGL_PROFILE, GLFW_OPENGL_CORE_PROFILE);
    glfwWindowHint(GLFW_OPENGL_DEBUG_CONTEXT, GL_TRUE);
    glfwWindowHint(GLFW_RESIZABLE, GL_FALSE);
205   GLFWwindow *window = glfwCreateWindow(WIDTH, HEIGHT, "fractalize", 0, 0);
    glfwMakeContextCurrent(window);
    if (!window) {
        fprintf(stderr, "glfw\n");
        return 1;
210   }
    glewInit();

    GLuint program = compile_program("shader", vert, frag);
    glUseProgram(program);
215   GLint utex = glGetUniformLocation(program, "tex");
    GLint umap = glGetUniformLocation(program, "map");
    GLint uix = glGetUniformLocation(program, "ix");
    GLint uzoom = glGetUniformLocation(program, "zoom");
    GLint udelta = glGetUniformLocation(program, "delta");
220   GLint ublend = glGetUniformLocation(program, "blend");
    glUniform1i(utex, 0);

```

```

glUniform1i(umap, 1);

GLuint vao;
225 glGenVertexArrays(1, &vao);
glBindVertexArray(vao);
GLuint vbo;
glGenBuffers(1, &vbo);
glBindBuffer(GL_ARRAY_BUFFER, vbo);
230 GLfloat vbo_data[] =
    { -1, -1, 0, 0
      , -1, 1, 0, 1
      , 1, -1, 1, 0
      , 1, 1, 1, 1
235 };
glBufferData(GL_ARRAY_BUFFER, 16 * sizeof(GLfloat), vbo_data, GL_STATIC_DRAW);
glVertexAttribPointer(0, 2, GL_FLOAT, GL_FALSE, 4 * sizeof(GLfloat), 0);
glVertexAttribPointer(1, 2, GL_FLOAT, GL_FALSE, 4 * sizeof(GLfloat), ((char *)↵
    ↵ 0) + 2 * sizeof(GLfloat));
240 glEnableVertexAttribArray(0);
glEnableVertexAttribArray(1);

GLuint tex[2];
glGenTextures(2, &tex[0]);

245 glActiveTexture(GL_TEXTURE0 + 0);
glBindTexture(GL_TEXTURE_2D_ARRAY, tex[0]);
glTexImage3D(GL_TEXTURE_2D_ARRAY, 0, GL_RGB, WIDTH, HEIGHT, COUNT, 0, GL_RGB, ↵
    ↵ GL_UNSIGNED_BYTE, &raw[0][0][0][0]);
glGenerateMipmap(GL_TEXTURE_2D_ARRAY);
glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_MIN_FILTER, ↵
    ↵ GL_LINEAR_MIPMAP_LINEAR);
250 glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_WRAP_S, GL_CLAMP_TO_EDGE);
glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_WRAP_T, GL_CLAMP_TO_EDGE);

for (int k = 0; k < COUNT - 1; ++k)
255 for (int j = 0; j < 16; ++j)
for (int i = 0; i < 16; ++i)
    srgb2lab(raw16[k][j][i][0]/255.0, raw16[k][j][i][1]/255.0, raw16[k][j][i]↵
        ↵ ][2]/255.0, &lab16[k][j][i][0], &lab16[k][j][i][1], &lab16[k][j][i]↵
        ↵ ][2]);

for (int k = 0; k < COUNT - 1; ++k)
260 for (int j = 0; j < 2; ++j)
for (int i = 0; i < 2; ++i)
{
    double l = 0;
    double a = 0;
265 double b = 0;
for (int jj = 0; jj < 8; ++jj)
for (int ii = 0; ii < 8; ++ii)
    {
270 l += lab16[k][8 * j + jj][8 * i + ii][0];
a += lab16[k][8 * j + jj][8 * i + ii][1];
b += lab16[k][8 * j + jj][8 * i + ii][2];
    }
l /= 8 * 8;

```

```

275     a /= 8 * 8;
        b /= 8 * 8;
        lab2[k][j][i][0] = 1;
        lab2[k][j][i][1] = a;
        lab2[k][j][i][2] = b;
    }
280
    for (int k = 0; k < COUNT - 1; ++k)
    for (int j = 0; j < 8; ++j)
    for (int i = 0; i < 8; ++i)
    {
285        double min_metric = 1.0 / 0.0;
        int min_index = -1;
        for (int kk = 0; kk < COUNT - 1; ++kk)
        {
290            if (kk == k) continue;
            double s = 0;
            for (int jj = 0; jj < 2; ++jj)
            for (int ii = 0; ii < 2; ++ii)
            for (int c = 0; c < 3; ++c)
            {
295                double x = lab16[k][2*j + jj][2*i + ii][c];
                double y = lab2[kk][jj][ii][c];
                double d = x - y;
                s += d * d;
            }
300            if (s < min_metric)
            {
                min_metric = s;
                min_index = kk;
            }
305        }
        graph[k][j][i] = min_index;
    }
    for (int j = 0; j < 8; ++j)
    for (int i = 0; i < 8; ++i)
310        graph[COUNT - 1][j][i] = 0;

    glActiveTexture(GL_TEXTURE0 + 1);
    glBindTexture(GL_TEXTURE_2D_ARRAY, tex[1]);
    glTexImage3D(GL_TEXTURE_2D_ARRAY, 0, GL_R32F, 8, 8, COUNT, 0, GL_RED, GL_FLOAT,
        &graph[0][0][0]);
315    glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
    glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
    glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_WRAP_S, GL_CLAMP_TO_EDGE);
    glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_WRAP_T, GL_CLAMP_TO_EDGE);

320    int ix = COUNT-1;
    int zoomi = 4;
    int zoomj = 4;
    int speed = 150;
    double bdx = 0, bdy = 0;
325    for (int frame = 1; frame <= 15 * 60 * 60; ++frame)
    {
        if ((frame % speed) == 0)
        {
            ix = graph[ix][zoomj][zoomi];

```

```

330     int mi = 0x7fffffff;
        for (int j = 0; j < 8; ++j)
        for (int i = 0; i < 8; ++i)
        {
            int k = graph[ix][j][i];
335             int m = visited[k];
                mi = m < mi ? m : mi;
        }
        int n = 0;
        for (int j = 0; j < 8; ++j)
340         for (int i = 0; i < 8; ++i)
            {
                int k = graph[ix][j][i];
                int m = visited[k];
                n += mi == m;
345            }
        int coin = rand() % n;
        n = 0;
        for (int j = 0; j < 8; ++j)
        for (int i = 0; i < 8; ++i)
350         {
            int k = graph[ix][j][i];
            int m = visited[k];
            if (mi == m)
            {
355                 if (coin == n)
                    {
                        zoomj = j;
                        zoomi = i;
                        visited[k] += 1;
360                    }
                n += 1;
            }
        }
    }
365    // zoom blending
    double k = ((frame % speed) + 0.5) / speed;
    double zoom = pow(8, k); // hardcoded power - grid size...
    double blend2 = 1 - cos(2 * 3.141592653 * (k + 0) / 3);
    double blend1 = 1 - cos(2 * 3.141592653 * (k + 1) / 3);
370    double blend0 = 1 - cos(2 * 3.141592653 * (k + 2) / 3);
    double blendt = blend0 + blend1 + blend2;
    blend0 /= blendt;
    blend1 /= blendt;
    blend2 /= blendt;
375    double dx = zoomi * 8 / (8 - 1.0);
    double dy = 8 - zoomj * 8 / (8 - 1.0);
    dx /= 4;
    dy /= 4;
    dx -= 1;
380    dy -= 1;
    bdx *= 0.95;
    bdy *= 0.95;
    bdx += 0.05 * dx;
    bdy += 0.05 * dy;
385    glUniform1i(uix, ix);
    glUniform1f(uzoom, zoom);

```

```

    glUniform2f(udelta, bdx, bdy);
    glUniform3f(ublend, blend0, blend1, blend2);
    glDrawArrays(GL_TRIANGLE_STRIP, 0, 4);
390   glfwSwapBuffers(window);
    glReadPixels(0, 0, WIDTH, HEIGHT, GL_RGB, GL_UNSIGNED_BYTE, &out[0][0][0]);
    printf("P6\n%d %d\n255\n", WIDTH, HEIGHT);
    for (int j = HEIGHT - 1; j >= 0; --j)
    {
395     fwrite(&out[j][0][0], WIDTH * 3, 1, stdout);
    }
    fflush(stdout);
    }
400 }

```

7 photo/Makefile

```

fractal-photo-mosaic: fractal-photo-mosaic.c
    gcc -std=c99 -Wall -Wextra -pedantic -O3 -o fractal-photo-mosaic fractal.c
    ↪ -photo-mosaic.c -lglfw -lGL -lGLEW -lm

```

8 photo/prepare.sh

```

#!/bin/sh
for i in *.jpeg *.png
do
    convert "${i}" -geometry 1920x1080^ -gravity center ↵
    ↪ -extent 1920x1080 -blur 0x32 "/tmp/
    ↪ /background.png"
5   convert "${i}" -geometry 1920x1080 -gravity center -alpha opaque -background ↵
    ↪ transparent -extent 1920x1080 "/tmp/foreground.png"
    composite -compose Over -gravity center "/tmp/foreground.png" "/tmp/background ↵
    ↪ .png" "${i}.ppm"
done
for i in *.ppm
do
10  cat "${i}" | tail -c $((1920 * 1080 * 3))
done > image.data
for i in *.ppm
do
    convert "${i}" -geometry '16x16!' "/tmp/thumb.ppm"
15  cat "/tmp/thumb.ppm" | tail -c $((16 * 16 * 3))
done > thumbs.data

```

9 photo/README.md

fractal-photo-mosaic

render a zooming fractal video from a collection of images

5

usage

mkdir images

10

cd images

```

wget *.jpeg *.png # needs exactly 103 images total, TODO FIXME hardcoding
../prepare.sh
cd ..
ln -s images/image.data
15 ln -s images/thumbs.data
make
./fractal-photo-mosaic |
ffmpeg -i soundtrack.wav -f image2pipe -codec ppm -framerate 60 -i - \
    -pix_fmt yuv420p -profile:v high -level:v 4.1 -b:v 20M -b:a 192k \
20 fractal-photo-mosaic.mkv

```

10 README

QUICK START

```

# get a computer with graphics drivers supporting OpenGL/GLSL 130
# on Debian-based systems (you might need multimedia repositories)
5 sudo apt install \
    build-essential \
    libglew1.5-dev \
    freeglut3-dev \
    libjack-jackd2-dev \
10 jackd \
    mjpegtools \
    mplayer \
    ffmpeg
# get the source, if you're reading this you probably already have
15 git clone http://code.mathr.co.uk/fractal-channel-hopping.git
cd fractal-channel-hopping/
git tag -ln99
git checkout v6 # or a different tag
# prepare videos
20 mkdir v
cd v
ln -s /path/to/some/videos/ "Channel 01"
ln -s /path/to/more/videos/ "Channel 02"
# etc, up to 12 channels
25 # start JACK server
../start.sh
# watch tv
# 'Shift-R' to start/stop recording
# 'F11' fullscreen
30 # 'Shift-Q' or 'ESC' to quit

```

NOTES

```

35 be patient during startup (takes a few seconds)
sometimes it doesn't quit cleanly, "killall mplayer" perhaps
tested with NVIDIA proprietary drivers and AMD open source drivers
recording is in PAL DVD format (..mpeg)

```

11 src/channel.c

```

/*
fractal-channel-hopping -- infinite fractal television zoom
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```

```

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*/

#define _DEFAULT_SOURCE

20  #include <pthread.h>
   #include <stdio.h>
   #include <stdlib.h>
   #include <string.h>
25  #include <unistd.h>

   #include "config.h"
   #include "channel.h"

30  void *channel_main(void *arg) {
   struct channel *channel = arg;
   if (channel->width == 256 && channel->height == 256) {
   int bytes = 256 * 256 + 128 * 128 * 2;
   const char *fmt = "mplayer -quiet -really-quiet -loop 0 -shuffle -aspect 1/1 ↵
   ↵ -vf scale=256:256 -ao 'jack:name=%s:port=fch.*%s_[1-2] ' -vo 'yuv4mpeg ↵
   ↵ :file=tmp/%s.fifo ' -fixed-vo '%s/'*.mp4 >'tmp/%s.mplayer.log' 2>&1 & ↵
   ↵ cat 'tmp/%s.fifo '";
35  int cmdlen = strlen(fmt) + 6 * strlen(channel->name) + 64;
   char *cmd = malloc(cmdlen);
   snprintf(cmd, cmdlen - 2, fmt, channel->name, channel->name, channel->name, ↵
   ↵ channel->name, channel->name, channel->name);
   cmd[cmdlen-1] = 0;
   FILE *video;
40  if ((video = popen(cmd, "r"))) {
   const char *vhdr25 = "YUV4MPEG2 W256 H256 F25:1 Ip A1:1\n";
   const char *vhdr50 = "YUV4MPEG2 W256 H256 F50:1 Ip A1:1\n";
   const char *fhdr = "FRAME\n";
   char hdr[64];
45  if (1 != fread(hdr, strlen(vhdr25), 1, video)) { channel->aborted = 1; ↵
   ↵ goto cleanup; }
   hdr[strlen(vhdr25)] = 0;
   if (strcmp(vhdr25, hdr) && strcmp(vhdr50, hdr)) { channel->aborted = 2; ↵
   ↵ goto cleanup; }
   while (! channel->quit) {
   if (1 != fread(hdr, strlen(fhdr), 1, video)) { channel->aborted = 3; ↵
   ↵ break; }
50  hdr[strlen(fhdr)] = 0;
   if (strcmp(fhdr, hdr)) { channel->aborted = 4; break; }
   if (1 != fread(channel->image, bytes, 1, video)) { channel->aborted = 5; ↵
   ↵ break; }

```

```

    }
    cleanup:
55     pclose(video);
    }
    free(cmd);
}
if (channel->aborted) {
60     fprintf(stderr, "channel '%s' aborted '%d'\n", channel->name, channel->
        ↵ aborted);
}
pthread_exit(0);
return 0;
}
65
struct channel *channel_start(const char *name) {
    struct channel *channel = calloc(1, sizeof(struct channel));
    // clear YUV to black
    memset(&channel->image[0], 0, VIDEO_WIDTH * VIDEO_HEIGHT);
70     memset(&channel->image[VIDEO_WIDTH * VIDEO_HEIGHT], 128, 2 * VIDEO_WIDTH/2 *
        ↵ VIDEO_HEIGHT/2);
    channel->name = strdup(name);
    channel->width = VIDEO_WIDTH;
    channel->height = VIDEO_HEIGHT;
    if (pthread_create(&channel->thread, 0, channel_main, channel)) {
75         free(channel->name);
        free(channel);
        return 0;
    }
    return channel;
80 }

int channel_stop(struct channel *channel) {
    channel->quit = 1;
    pthread_join(channel->thread, 0);
85     int r = channel->aborted;
    free(channel->name);
    free(channel);
    return r;
}

```

12 src/channel.h

```

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```

```

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*/

#ifdef CHANNEL_H
20 #define CHANNEL_H 1

#include <pthread.h>

#include "config.h"
25
struct channel {
    pthread_t thread;
    char *name;
    int quit;
30    int aborted;
    int width;
    int height;
    unsigned char image[VIDEO_WIDTH * VIDEO_HEIGHT + 2 * VIDEO_WIDTH/2 * 2
        ↵ VIDEO_HEIGHT/2];
};
35
struct channel *channel_start(const char *name);
int channel_stop(struct channel *channel);

#endif

```

13 src/config.h

```

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*/

#ifdef CONFIG_H
20 #define CONFIG_H 1

#define VIDEO_WIDTH 256
#define VIDEO_HEIGHT 256
#define GRID_WIDTH 16
25 #define GRID_HEIGHT 16

// #define TEXTURE_SIZE 256
#define TEXTURE_X 1.0 f
#define TEXTURE_Y 0.5625 f

```

```

30 #define CHANNEL_COUNT_MAX 16

#define OUTPUT_WIDTH 1024
#define OUTPUT_HEIGHT 576
35 #endif

```

14 src/fch.frag

```

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*/

#version 130

20 uniform sampler2D images; // 4x4 tile sheet
uniform vec3 matches[12]; // hardcoded maximum channels
uniform int focus;
uniform float blend0;
25 uniform float blend1;
uniform float blend2;

vec3 get(int n, vec2 p, float bias, bool wrap) {
30     int j = int(floor(float(n) / 4.0));
    int i = n - 4 * j;
    vec2 p1 = p;
    if (wrap) {
        float k = pow(2.0, 8.0 - bias);
        p1 = floor(p1 * k) / k;
35     }
    p1 *= 254.0 / 256.0;
    p1 += 1.0 / 256.0;
    vec2 q = (vec2(float(i), float(j)) + p1) / 4.0;
    return textureLod(images, q, bias).rgb;
40 }

int match(int def, vec3 c) {
    float d = 1024.0;
    int m = def;
45     for (int i = 0; i < 12; ++i) {
        if (length(matches[i]) > 0.0) {
            float d2 = length(c - matches[i]);

```

```

        if (d2 < d) {
            d = d2;
50         m = i;
        }
    }
}
return m;
55 }

void main(void) {
    int f0 = focus;
    vec2 p0 = gl_TexCoord[0].xy;
60    vec3 c0 = get(f0, p0, 0.0, false);
    vec3 ca = get(f0, p0, 4.0, true);

    int f1 = match(f0, ca);
    vec2 p1 = 16.0 * p0; p1 -= floor(p1);
65    vec3 c1 = get(f1, p1, 0.0, false);
    vec3 cb = get(f1, p1, 4.0, true);

    int f2 = match(f1, cb);
    vec2 p2 = 16.0 * p1; p2 -= floor(p2);
70    vec3 c2 = get(f2, p2, 0.0, false);

    float channel[12];
    channel[0] = 0.0;
    channel[1] = 0.0;
75    channel[2] = 0.0;
    channel[3] = 0.0;
    channel[4] = 0.0;
    channel[5] = 0.0;
    channel[6] = 0.0;
80    channel[7] = 0.0;
    channel[8] = 0.0;
    channel[9] = 0.0;
    channel[10] = 0.0;
    channel[11] = 0.0;
85    channel[f0] += blend0;
    channel[f1] += blend1;
    channel[f2] += blend2;
    gl_FragData[0] = vec4(blend0 * c0 + blend1 * c1 + blend2 * c2, 1.0);
    gl_FragData[1] = vec4(channel[0], channel[1], channel[2], channel[3]);
90    gl_FragData[2] = vec4(channel[4], channel[5], channel[6], channel[7]);
    gl_FragData[3] = vec4(channel[8], channel[9], channel[10], channel[11]);
}

```

15 src/list.c

```

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```

```

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    */

#include <assert.h>
20 #include "list.h"

void list_init(struct list *l) {
    assert(l);
    l->head = &(l->headNode);
25   l->tail = &(l->tailNode);
    l->head->pred = 0;
    l->head->next = l->tail;
    l->tail->pred = l->head;
    l->tail->next = 0;
30 }

int list_ishead(struct node *n) {
    assert(n);
    return !n->pred;
35 }

int list_istail(struct node *n) {
    assert(n);
    return !n->next;
40 }

int list_isempty(struct list *l) {
    assert(l && l->head && l->tail);
    return l->head->next == l->tail;
45 }

int list_length(struct list *l) {
    struct node *n = l->head->next;
    int i = 0;
50   while (n != l->tail) {
        n = n->next;
        i++;
    }
    return i;
55 }

void list_remove(struct node *n) {
    assert(n && n->pred && n->next);
    n->pred->next = n->next;
60   n->next->pred = n->pred;
    n->next = 0;
    n->pred = 0;
}

65 void list_insertbefore(struct node *n, struct node *beforethis) {
    assert(n && beforethis && beforethis->pred);
```

```

    n->next = beforethis;
    n->pred = beforethis->pred;
    beforethis->pred->next = n;
70   beforethis->pred = n;
    }

void list_insertafter(struct node *n, struct node *afterthis) {
    assert(n && afterthis && afterthis->next);
75   n->next = afterthis->next;
    n->pred = afterthis;
    afterthis->next->pred = n;
    afterthis->next = n;
    }
80

void list_inserttail(struct list *l, struct node *n) {
    assert(l);
    list_insertbefore(n, l->tail);
    }
85

struct node *list_removehead(struct list *l) {
    assert(l && ! list_isempty(l));
    struct node *n = l->head->next;
    list_remove(n);
90   return n;
    }

```

16 src/list.h

```

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*/

#ifdef LIST_H
20 #define LIST_H 1

    struct node {
        struct node *next;
        struct node *pred;
25 };

    struct list {
        struct node *head;
        struct node *tail;

```

```

30     // private
        struct node headNode;
        struct node tailNode;
    };

35     void list_init(struct list *l);
        int list_ishead(struct node *n);
        int list_istail(struct node *n);
        int list_isempty(struct list *l);
        int list_length(struct list *l);
40     void list_remove(struct node *n);
        void list_insertbefore(struct node *n, struct node *beforethis);
        void list_insertafter(struct node *n, struct node *afterthis);
        void list_inserttail(struct list *l, struct node *n);
        struct node *list_removehead(struct list *l);
45
#endif

```

17 src/main.c

```

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*/

#define _DEFAULT_SOURCE
20 #define _POSIX_C_SOURCE 200809

#include <assert.h>
#include <math.h>
#include <signal.h>
25 #include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>
#include <unistd.h>

30 #include <GL/glew.h>
#include <GL/glut.h>

#include <jack/jack.h>

35 #include "channel.h"
#include "record.h"

```

```

#include "fch.frag.c"
#include "yuv2rgb.frag.c"
40
int max(int x, int y) {
    return x > y ? x : y;
}

45 unsigned int roundtwo(unsigned int x) {
    assert(x <= 1u << 31u); // termination condition
    unsigned int y = 1;
    while (y < x) y <<= 1;
    return y;
50 }

unsigned int logtwo(unsigned int x) {
    assert(x <= 1u << 31u); // termination condition
    unsigned int y = 1, z = 0;
55     while (y < x) { y <<= 1; z += 1; };
    return z;
}

int focus = 0;
60 int speed = 75;
int frames = 0;
int tframes = 0;

int count;
65 struct channel **channels;

struct record *recorder = 0;

int winw, winh;
70 int tsize;
GLuint texiny, texinu, texinv, timages, toutput, tmatch[3]; // hardcoded: (12) ↗
    ↙ channels / 4
GLuint fbo;

// fractalization shader
75 GLhandleARB prog;
GLhandleARB frag;
GLint uimages, umatches, ufocus, ublend0, ublend1, ublend2;
GLfloat vmatches[4 * 4][3];

80 // yuv2rgb shader
GLhandleARB prog_yuv2rgb;
GLhandleARB frag_yuv2rgb;
GLint yuv2rgb_y, yuv2rgb_u, yuv2rgb_v;

85 double zoom;
int zoomi;
int zoomj;
double blend0;
double blend1;
90 double blend2;

jack_client_t *jclient;
jack_port_t *jporto[2];

```

```

jack_port_t *jport[CHANNEL_COUNT_MAX][2];
95 float jlevel[2][CHANNEL_COUNT_MAX];
int jwhich = 0;

void errorcb(const char *desc) {
    fprintf(stderr, "JACK error: %s\n", desc);
100 }

void shutdowncb(void *arg) {
    exit(1);
}

105 int processcb(jack_nframes_t nframes, void *arg) {
    jack_default_audio_sample_t *in[CHANNEL_COUNT_MAX][2], *out[2];
    for (int c = 0; c < count; ++c) {
        for (int k = 0; k < 2; ++k) {
110             in[c][k] = (jack_default_audio_sample_t *) jack_port_get_buffer(jport[c][k]
                ↪ ], nframes);
        }
    }
    out[0] = (jack_default_audio_sample_t *) jack_port_get_buffer(jporto[0], ↪
        ↪ nframes);
    out[1] = (jack_default_audio_sample_t *) jack_port_get_buffer(jporto[1], ↪
        ↪ nframes);
115 for (jack_nframes_t i = 0; i < nframes; ++i) {
    for (int k = 0; k < 2; ++k) {
        jack_default_audio_sample_t o = 0;
        for (int c = 0; c < count; ++c) {
120             o += jlevel[jwhich][c] * in[c][k][i];
        }
        out[k][i] = o;
    }
}
return 0;
125 }

void realloctexture(GLuint t, GLenum fmt, float r, float g, float b) {
    // resize texture
    glBindTexture(GL_TEXTURE_2D, t);
130 glTexImage2D(GL_TEXTURE_2D, 0, fmt, tsize, tsize, 0, fmt, GL_UNSIGNED_BYTE, 0) ↪
        ↪ ;
    glBindTexture(GL_TEXTURE_2D, 0);
    // clear texture
    glViewport(0, 0, tsize, tsize);
    glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
135 glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↪
        ↪ GL_TEXTURE_2D, t, 0);
    GLenum dbs[] = { GL_COLOR_ATTACHMENT0_EXT };
    glDrawBuffers(1, dbs);
    glClearColor(r, g, b, 0);
    glClear(GL_COLOR_BUFFER_BIT);
140 glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↪
        ↪ GL_TEXTURE_2D, 0, 0);
    glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
}

void reshapecb(int w, int h) {

```

```

145     if (recorder && (winw != w || winh != h)) {
        record_stop(recorder);
        recorder = 0;
    }
    winw = w;
150    winh = h;
    int oldtsize = tsize;
    tsize = roundtwo(max(w, h));
    if (oldtsize != tsize) {
        realloctexture(toutput, GL_RGBA, 0, 0, 0);
155        realloctexture(tmatch[0], GL_RGBA, 0, 0, 0);
        realloctexture(tmatch[1], GL_RGBA, 0, 0, 0);
        realloctexture(tmatch[2], GL_RGBA, 0, 0, 0);
    }
}
160 void displaycb(void) {
    // upload channels of video to tile sheet
    {
        // upload YUV planes
165        glActiveTexture(GL_TEXTURE0);
        glBindTexture(GL_TEXTURE_2D, texiny);
        for (int c = 0; c < count; ++c) {
            glTexSubImage2D(GL_TEXTURE_2D, 0, (c % 4) * VIDEO_WIDTH, (c / 4) * ↵
                ↵ VIDEO_HEIGHT, VIDEO_WIDTH, VIDEO_HEIGHT, GL_LUMINANCE, ↵
                ↵ GL_UNSIGNED_BYTE, &channels[c]->image[0]);
        }
170        glActiveTexture(GL_TEXTURE1);
        glBindTexture(GL_TEXTURE_2D, texinu);
        for (int c = 0; c < count; ++c) {
            glTexSubImage2D(GL_TEXTURE_2D, 0, (c % 4) * VIDEO_WIDTH/2, (c / 4) * ↵
                ↵ VIDEO_HEIGHT/2, VIDEO_WIDTH/2, VIDEO_HEIGHT/2, GL_LUMINANCE, ↵
                ↵ GL_UNSIGNED_BYTE, &channels[c]->image[VIDEO_WIDTH * VIDEO_HEIGHT]);
        }
175        glActiveTexture(GL_TEXTURE2);
        glBindTexture(GL_TEXTURE_2D, texinv);
        for (int c = 0; c < count; ++c) {
            glTexSubImage2D(GL_TEXTURE_2D, 0, (c % 4) * VIDEO_WIDTH/2, (c / 4) * ↵
                ↵ VIDEO_HEIGHT/2, VIDEO_WIDTH/2, VIDEO_HEIGHT/2, GL_LUMINANCE, ↵
                ↵ GL_UNSIGNED_BYTE, &channels[c]->image[VIDEO_WIDTH * VIDEO_HEIGHT + ↵
                ↵ VIDEO_WIDTH/2 * VIDEO_HEIGHT/2]);
        }
180        // convert to RGB
        glViewport(0, 0, 1024, 1024);
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
        glOrtho(0, 1, 0, 1, -1, 1);
185        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
        glFramebufferTexture2D(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↵
            ↵ GL_TEXTURE_2D, timages, 0);
        GLenum dbs[] = { GL_COLOR_ATTACHMENT0_EXT };
        glDrawBuffers(1, dbs);
        glUseProgramObjectARB(prog_yuv2rgb);
190        glUniform1i(yuv2rgb_y, 0);
        glUniform1i(yuv2rgb_u, 1);
        glUniform1i(yuv2rgb_v, 2);
        glBegin(GL_QUADS); {

```

```

195     glTexCoord2f(0, 0); glVertex2f(0, 0);
        glTexCoord2f(1, 0); glVertex2f(1, 0);
        glTexCoord2f(1, 1); glVertex2f(1, 1);
        glTexCoord2f(0, 1); glVertex2f(0, 1);
    } glEnd();
    glUseProgramObjectARB(0);
200    glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↵
        ↵ GL_TEXTURE_2D, 0, 0);
    glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
    glBindTexture(GL_TEXTURE_2D, 0);
    glActiveTexture(GL_TEXTURE1);
    glBindTexture(GL_TEXTURE_2D, 0);
205    glActiveTexture(GL_TEXTURE0);
    glBindTexture(GL_TEXTURE_2D, timages);
    glGenerateMipmap(GL_TEXTURE_2D);
    glGetTexImage(GL_TEXTURE_2D, 8 /* hardcoded log2(4*256) - 2 */, GL_RGB, ↵
        ↵ GL_FLOAT, vmatches);
    glBindTexture(GL_TEXTURE_2D, 0);
210 }

// set up zooming view
glViewport(0, 0, winw, winh);
{
215    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    glOrtho(0, GRID_WIDTH, 0, GRID_HEIGHT, -1, 1);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
220    double dx = zoomi * GRID_WIDTH / (GRID_WIDTH - 1.0);
    double dy = GRID_HEIGHT - zoomj * GRID_HEIGHT / (GRID_HEIGHT - 1.0);
    glTranslatef(dx, dy, 0);
    glScalef(zoom, zoom, zoom);
    glTranslatef(-dx, -dy, 0);
225 }

// mega shader action
glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↵
    ↵ GL_TEXTURE_2D, toutput, 0);
230 glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT1_EXT, ↵
    ↵ GL_TEXTURE_2D, tmatch[0], 0);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT2_EXT, ↵
    ↵ GL_TEXTURE_2D, tmatch[1], 0);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT3_EXT, ↵
    ↵ GL_TEXTURE_2D, tmatch[2], 0);
GLenum dbs[] = { GL_COLOR_ATTACHMENT0_EXT, GL_COLOR_ATTACHMENT1_EXT, ↵
    ↵ GL_COLOR_ATTACHMENT2_EXT, GL_COLOR_ATTACHMENT3_EXT };
glDrawBuffers(4, dbs);
235 glUseProgramObjectARB(prog);
glBindTexture(GL_TEXTURE_2D, timages);
glUniform1i(uimages, 0);
glUniform3fv(umatches, 12, &vmatches[0][0]);
glUniform1i(ufocus, focus);
240 glUniform1f(ublend0, blend0);
glUniform1f(ublend1, blend1);
glUniform1f(ublend2, blend2);
glBegin(GL_QUADS); {

```

```

    glTexCoord2f(0, 1); glVertex2f(0, 0);
245   glTexCoord2f(1, 1); glVertex2f(GRID_WIDTH, 0);
    glTexCoord2f(1, 0); glVertex2f(GRID_WIDTH, GRID_HEIGHT);
    glTexCoord2f(0, 0); glVertex2f(0, GRID_HEIGHT);
} glEnd();
glBindTexture(GL_TEXTURE_2D, 0);
250 glUseProgramObjectARB(0);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↵
    ↵ GL_TEXTURE_2D, 0, 0);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT1_EXT, ↵
    ↵ GL_TEXTURE_2D, 0, 0);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT2_EXT, ↵
    ↵ GL_TEXTURE_2D, 0, 0);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT3_EXT, ↵
    ↵ GL_TEXTURE_2D, 0, 0);
255 glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);

// show output image
glLoadIdentity();
glBindTexture(GL_TEXTURE_2D, toutput);
260 glBegin(GL_QUADS); {
    float tx = winw * 1.0f / tsize;
    float ty = winh * 1.0f / tsize;
    glTexCoord2f(0, 0); glVertex2f(0, 0);
    glTexCoord2f(tx, 0); glVertex2f(GRID_WIDTH, 0);
265   glTexCoord2f(tx, ty); glVertex2f(GRID_WIDTH, GRID_HEIGHT);
    glTexCoord2f(0, ty); glVertex2f(0, GRID_HEIGHT);
} glEnd();
glBindTexture(GL_TEXTURE_2D, 0);

270 // grab auxiliary images to audio mixer
glBindTexture(GL_TEXTURE_2D, tmatch[0]);
glGenerateMipmap(GL_TEXTURE_2D);
glGetTexImage(GL_TEXTURE_2D, logtwo(tsize), GL_RGBA, GL_FLOAT, &jlevel[1 - ↵
    ↵ jwhich][0]);
glBindTexture(GL_TEXTURE_2D, tmatch[1]);
275 glGenerateMipmap(GL_TEXTURE_2D);
glGetTexImage(GL_TEXTURE_2D, logtwo(tsize), GL_RGBA, GL_FLOAT, &jlevel[1 - ↵
    ↵ jwhich][4]);
glBindTexture(GL_TEXTURE_2D, tmatch[2]);
glGenerateMipmap(GL_TEXTURE_2D);
glGetTexImage(GL_TEXTURE_2D, logtwo(tsize), GL_RGBA, GL_FLOAT, &jlevel[1 - ↵
    ↵ jwhich][8]);
280 glBindTexture(GL_TEXTURE_2D, 0);
double s = 0;
for (int c = 0; c < count; ++c) {
    s += jlevel[1 - jwhich][c];
}
285 if (!s) {
    s = 1;
}
for (int c = 0; c < count; ++c) {
    jlevel[1 - jwhich][c] /= s;
290 }
jwhich = 1 - jwhich;

// PPM recording on stdout

```

```

    if (recorder) {
295     record_frame(recorder);
    }

    glutSwapBuffers();

300    // bug free code?
    glutReportErrors();

    // we done a frame
    tframes++;
305    frames++;
}

float smatch[4][16][4][16][3];
float matches[4][4][3];
310

struct timespec clock0;
struct timespec clock1;

void timercb(int v) {
315    glutTimerFunc(1, timercb, v);
    clock_gettime(CLOCK_REALTIME, &clock1);
    double dt = (clock1.tv_sec - clock0.tv_sec) + 1.0e-9 * (clock1.tv_nsec -
        ↵ clock0.tv_nsec);
    if (dt < 0.04 * tframes) {
320        return;
    }
    if (frames == speed) {
        // refocus
        glBindTexture(GL_TEXTURE_2D, timages);
        glGenerateMipmap(GL_TEXTURE_2D);
325        glGetTexImage(GL_TEXTURE_2D, 4, GL_RGB, GL_FLOAT, &smatch[0][0][0][0][0]);
        glGetTexImage(GL_TEXTURE_2D, 8, GL_RGB, GL_FLOAT, &matches[0][0][0]);
        glBindTexture(GL_TEXTURE_2D, 0);
        float ml = 65536.0;
        int mi = focus;
330        for (int c = 0; c < count; ++c) {
            float s = 0;
            for (int k = 0; k < 3; ++k) {
                float ds = smatch[focus / 4][zoomj][focus % 4][zoomi][k] - vmatches[c][k]
                    ↵ ];
                s += ds * ds;
335            }
            if (s < ml) {
                ml = s;
                mi = c;
            }
340        }
        focus = mi;
        ml = 65536.0;
        for (int c = 0; c < count; ++c) {
            float s = 0;
345            for (int k = 0; k < 3; ++k) {
                float ds = matches[focus / 4][focus % 4][k] - vmatches[c][k];
                s += ds * ds;
            }
        }
    }
}

```

```

    if (s < ml) {
350         ml = s;
            mi = c;
        }
    }
    focus = mi;
355    // self-centering random walk
    if (rand() % 8) {
        int coin = rand() % (GRID.WIDTH - 1);
        zoomi += coin < zoomi ? -1 : 1;
    }
360    if (rand() % 8) {
        int coin = rand() % (GRID.HEIGHT - 1);
        zoomj += coin < zoomj ? -1 : 1;
    }
    frames = 0;
365 }

// zoom blending
double k = frames * 1.0 / speed;
zoom = pow(16, k); // hardcoded power - grid size ...
370 blend2 = 1 - cos(2 * 3.141592653 * (k + 0) / 3);
    blend1 = 1 - cos(2 * 3.141592653 * (k + 1) / 3);
    blend0 = 1 - cos(2 * 3.141592653 * (k + 2) / 3);
    double blendt = blend0 + blend1 + blend2;
    blend0 /= blendt;
375    blend1 /= blendt;
    blend2 /= blendt;

    glutPostRedisplay();
}
380 int fullscreen = 0;

void keyboardcb(unsigned char key, int x, int y) {
    switch (key) {
385     case 'R':
        if (recorder) {
            record_stop(recorder);
            recorder = 0;
        } else {
390         recorder = record_start(winw, winh, jclient, jporto);
        }
        break;
    case 'Q':
    case 27:
395     exit(0);
        break;
    }
}

400 void keyspecialcb(int key, int x, int y) {
    switch (key) {
    case GLUT_KEY_F11:
        fullscreen = !fullscreen;
        if (fullscreen) {
405         glutFullScreen();
        }
    }
}

```

```

        glutSetCursor(GLUT_CURSOR_NONE);
    } else {
        glutReshapeWindow(OUTPUT_WIDTH, OUTPUT_HEIGHT);
        glutSetCursor(GLUT_CURSOR_INHERIT);
410    }
        break;
    }
}

415 void exitcb(void) {
    if (recorder) {
        record_stop(recorder);
        recorder = 0;
    }
420    jack_client_close(jclient);
    killpg(getpgrp(), SIGKILL); // kill all our processes
    for (int c = 0; c < count; ++c) {
        channel_stop(channels[c]);
    }
425    free(channels);
}

int main(int argc, char **argv) {

430    // initialisation
    if (argc <= 1) { return 1; }
    count = argc - 1;
    channels = calloc(count, sizeof(struct channel *));

435    srand(time(0));
    zoomj = rand() % GRID_HEIGHT;
    zoomi = rand() % GRID_WIDTH;
    glutInitWindowSize(OUTPUT_WIDTH, OUTPUT_HEIGHT);
    glutInit(&argc, argv);
440    glutInitDisplayMode(GLUT_RGBA | GLUT_DOUBLE);
    glutCreateWindow("fractal-channel-hopping");
    glewInit();

    // set up jack first

445    jack_set_error_function(errorcb);
    if (!(jclient = jack_client_open("fch", 0, 0))) {
        fprintf(stderr, "jack server not running?\n");
        return 1;
450    }
    jack_set_process_callback(jclient, processcb, 0);
    jack_on_shutdown(jclient, shutdowncb, 0);
    for (int c = 0; c < count; ++c) {
        for (int k = 0; k < 2; ++k) {
455            char namebuf[64];
            snprintf(namebuf, 62, "%s_%d", argv[c + 1], k + 1);
            namebuf[63] = 0;
            jport[c][k] = jack_port_register(jclient, namebuf, JACK_DEFAULT_AUDIO_TYPE,
                ↵, JackPortIsInput, 0);
        }
460    }
    for (int k = 0; k < 2; ++k) {

```

```

    char namebuf[64];
    snprintf(namebuf, 62, "output_%d", k + 1);
    namebuf[63] = 0;
465     jporto[k] = jack_port_register(jclient, namebuf, JACK_DEFAULT_AUDIO_TYPE, ↵
        ↵ JackPortIsOutput, 0);
    }
    if (jack_activate(jclient)) {
        fprintf(stderr, "cannot activate JACK client");
        return 1;
470     }
    jack_connect(jclient, "fch:output_1", "system:playback_1");
    jack_connect(jclient, "fch:output_2", "system:playback_2");

    // then start streaming channels which connect to us via jack
475     for (int c = 0; c < count; ++c) {
        channels[c] = channel_start(argv[c + 1]);
    }

480     // and prepare the display

    glHint(GL_GENERATE_MIPMAP_HINT, GL_FASTEST);
    glEnable(GL_TEXTURE_2D);
    glGenFramebuffersEXT(1, &fbo);
485

    // YUV planar video
    tsize = 1024;
    glGenTextures(1, &texiny);
    realloctexture(texiny, GL_LUMINANCE, 0, 0, 0);
490     glBindTexture(GL_TEXTURE_2D, texiny);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
    glBindTexture(GL_TEXTURE_2D, 0);
    tsize /= 2;
495     glGenTextures(1, &texinu);
    realloctexture(texinu, GL_LUMINANCE, 0.5, 0.5, 0.5);
    glBindTexture(GL_TEXTURE_2D, texinu);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
500     glBindTexture(GL_TEXTURE_2D, 0);
    glGenTextures(1, &texinv);
    realloctexture(texinv, GL_LUMINANCE, 0.5, 0.5, 0.5);
    glBindTexture(GL_TEXTURE_2D, texinv);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
505     glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
    glBindTexture(GL_TEXTURE_2D, 0);

    // RGB interleaved video
    tsize = 1024;
510     glGenTextures(1, &timages);
    realloctexture(timages, GL_RGBA, 0, 0, 0);
    glBindTexture(GL_TEXTURE_2D, timages);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR_MIPMAP_LINEAR) ↵
        ↵ ;
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
515     glBindTexture(GL_TEXTURE_2D, 0);

```

```

// RGB output
tsize = roundtwo(max(OUTPUT_WIDTH, OUTPUT_HEIGHT));
glGenTextures(1, &toutput);
520 realloctexture(toutput, GL_RGBA, 0, 0, 0);
glBindTexture(GL_TEXTURE_2D, toutput);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
glBindTexture(GL_TEXTURE_2D, 0);
525 glGenTextures(3, &tmatch[0]);
realloctexture(tmatch[0], GL_RGBA, 0, 0, 0);
realloctexture(tmatch[1], GL_RGBA, 0, 0, 0);
realloctexture(tmatch[2], GL_RGBA, 0, 0, 0);

530 // fractalization shader
GLint success;
prog = glCreateProgramObjectARB();
frag = glCreateShaderObjectARB(GL_FRAGMENT_SHADER_ARB);
glShaderSourceARB(frag, 1, &fch_frag, 0);
535 glCompileShaderARB(frag);
glAttachObjectARB(prog, frag);
glLinkProgramARB(prog);
glGetObjectParameterivARB(prog, GL_OBJECT_LINK_STATUS_ARB, &success);
if (!success) {
540     GLhandleARB obj = prog;
     int infologLength = 0;
     int maxLength;
     if (glIsShader(obj)) {
         glGetShaderiv(obj, GL_INFO_LOG_LENGTH, &maxLength);
545     } else {
         glGetProgramiv(obj, GL_INFO_LOG_LENGTH, &maxLength);
     }
     char *infoLog = malloc(maxLength);
     if (!infoLog) {
550         exit(1);
     }
     if (glIsShader(obj)) {
         glGetShaderInfoLog(obj, maxLength, &infologLength, infoLog);
     } else {
555         glGetProgramInfoLog(obj, maxLength, &infologLength, infoLog);
     }
     if (infologLength > 0) {
         fprintf(stderr, "%s\n", infoLog);
     }
560     free(infoLog);
     exit(1);
}
uimages = glGetUniformLocationARB(prog, "images");
umatches = glGetUniformLocationARB(prog, "matches");
565 ufocus = glGetUniformLocationARB(prog, "focus");
ublend0 = glGetUniformLocationARB(prog, "blend0");
ublend1 = glGetUniformLocationARB(prog, "blend1");
ublend2 = glGetUniformLocationARB(prog, "blend2");

570 // YUV2RGB shader
prog_yuv2rgb = glCreateProgramObjectARB();
frag_yuv2rgb = glCreateShaderObjectARB(GL_FRAGMENT_SHADER_ARB);
glShaderSourceARB(frag_yuv2rgb, 1, &yuv2rgb_frag, 0);

```

```

glCompileShaderARB( frag_yuv2rgb );
575 glAttachObjectARB( prog_yuv2rgb, frag_yuv2rgb );
glLinkProgramARB( prog_yuv2rgb );
glGetObjectParameterivARB( prog_yuv2rgb, GL_OBJECT_LINK_STATUS_ARB, &success );
if (! success) {
    GLhandleARB obj = prog_yuv2rgb;
580 int infologLength = 0;
int maxLength;
if ( glIsShader( obj ) ) {
    glGetShaderiv( obj, GL_INFO_LOG_LENGTH, &maxLength );
} else {
585 glGetProgramiv( obj, GL_INFO_LOG_LENGTH, &maxLength );
}
char *infoLog = malloc( maxLength );
if (!infoLog) {
    exit( 1 );
590 }
if ( glIsShader( obj ) ) {
    glGetShaderInfoLog( obj, maxLength, &infologLength, infoLog );
} else {
    glGetProgramInfoLog( obj, maxLength, &infologLength, infoLog );
595 }
if ( infologLength > 0 ) {
    fprintf( stderr, "%s\n", infoLog );
}
free( infoLog );
600 exit( 1 );
}
yuv2rgb_y = glGetUniformLocationARB( prog_yuv2rgb, "y" );
yuv2rgb_u = glGetUniformLocationARB( prog_yuv2rgb, "u" );
yuv2rgb_v = glGetUniformLocationARB( prog_yuv2rgb, "v" );
605
// callbacks
glutKeyboardFunc( keyboardcb );
glutSpecialFunc( keyspecialcb );
glutReshapeFunc( reshapecb );
610 glutDisplayFunc( displaycb );
glutTimerFunc( 1, timercb, 1 );
atexit( exitcb );

// main loop
615 clock_gettime( CLOCK_REALTIME, &clock0 );
glutMainLoop();
return 0;
}

```

18 src/Makefile

```

# fractal-channel-hopping -- infinite fractal television zoom
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CC=gcc
CFLAGS=-std=c99 -Wall -pedantic -Wextra -Wno-unused-parameter -O3 -march=native ↵
↳ -pthread -lGLEW -lGL -lglut -ljack -lm

20 BINARY = fractal-channel-hopping
SOURCES = channel.c record.c pfifo.c list.c main.c
HEADERS = channel.h record.h pfifo.h list.h config.h
GENHEAD = fch.frag.c yuv2rgb.frag.c

25 all: $(BINARY)

clean:
    -rm $(BINARY) $(GENHEAD)

30 .SUFFIXES:
.PHONY: all clean

$(BINARY): $(SOURCES) $(HEADERS) $(GENHEAD)
    $(CC) $(CFLAGS) -o $(BINARY) $(SOURCES)

35 %.frag.c: %.frag s2c.sh
    ./s2c.sh $_frag < $< > $@

```

19 src/pfifo.c

```

/*
fractal-channel-hopping -- infinite fractal television zoom
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*/

#include <assert.h>
20 #include <string.h>
#include "pfifo.h"

void *pfifo_consumerthread(void *);

25 struct pfifo *pfifo_create(pfifo_consumer *consumer, void *consumerdata) {

```

```

    struct pfifo *p = malloc(sizeof(struct pfifo));
    if (!p) return 0;
    list_init(&(p->list));
    p->running = 1;
30  p->consumer = consumer;
    p->consumerdata = consumerdata;
    p->mutex = malloc(sizeof(pthread_mutex_t));
    pthread_mutex_init(p->mutex, 0);
    p->nonempty = malloc(sizeof(pthread_cond_t));
35  pthread_cond_init(p->nonempty, 0);
    pthread_create(&(p->thread), 0, pfifo_consumerthread, p);
    return p;
}

40 void pfifo_destroy(struct pfifo *p) {
    p->running = 0;
    pthread_join(p->thread, 0);
    // FIXME proper cleanup...
}

45 void pfifo_enqueue(struct pfifo *p, size_t length, const void *data) {
    struct pfifo_node *n = malloc(sizeof(struct pfifo_node));
    assert(n);
    n->length = length;
50  n->data = malloc(length);
    assert(n->data);
    memcpy(n->data, data, length);
    pthread_mutex_lock(p->mutex);
    list_inserttail(&(p->list), &(n->node));
55  pthread_mutex_unlock(p->mutex);
    pthread_cond_signal(p->nonempty);
}

void *pfifo_consumerthread(void *fifo) {
60  struct pfifo *p = fifo;
    pthread_mutex_lock(p->mutex);
    while (p->running) {
        while (list_isempty(&(p->list))) pthread_cond_wait(p->nonempty, p->mutex);
        struct pfifo_node *n = (struct pfifo_node *) list_removehead(&(p->list));
65  p->consumer(p->consumerdata, n->length, n->data);
        free(n->data);
        free(n);
    }
    pthread_exit(0);
70  return 0;
}

```

20 src/pfifo.h

```

/*
fractal-channel-hopping -- infinite fractal television zoom
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```

```

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    along with this program.  If not, see <http://www.gnu.org/licenses/>.
    */

    #ifndef PFIFO_H
20   #define PFIFO_H 1

    #include <stdlib.h>
    #include <pthread.h>
    #include "list.h"

25   typedef void (pfifo_consumer)(void *, size_t, void *);

    struct pfifo_node {
        struct node node;
30   size_t length;
        void *data;
    };

    struct pfifo {
35   pfifo_consumer *consumer;
        void *consumerdata;
        struct list list;
        pthread_t thread;
        pthread_mutex_t *mutex;
40   pthread_cond_t *nonempty;
        int running;
    };

    struct pfifo *pfifo_create(pfifo_consumer *consumer, void *consumerdata);
45 void pfifo_destroy(struct pfifo *fifo);
    void pfifo_enqueue(struct pfifo *fifo, size_t length, const void *data);

    #endif

```

21 src/record.c

```

/*
    fractal-channel-hopping -- infinite fractal television zoom
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```

```

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*/

#define _DEFAULT_SOURCE

20 #include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <time.h>

25 #include <GL/glew.h>
#include <jack/jack.h>

#include "pfifo.h"
30 #include "record.h"

void record_writer(void *arg, size_t l, void *data) {
    struct record *record = arg;
    unsigned char *buffer = data;
35     fwrite(record->header, strlen(record->header), 1, record->ppm);
    for (int y = record->height - 1; y >= 0; --y) {
        fwrite(buffer + record->width * y * 3, record->width * 3, 1, record->ppm);
    }
    if (! jack_port_connected_to(record->jport [0], "record:input_1")) {
40         jack_connect(record->jclient, jack_port_name(record->jport [0]), "record:↵
            ↵ input_1");
    }
    if (! jack_port_connected_to(record->jport [1], "record:input_2")) {
        jack_connect(record->jclient, jack_port_name(record->jport [1]), "record:↵
            ↵ input_2");
    }
45 }

struct record *record_start(int w, int h, jack_client_t *jclient, jack_port_t **↵
    ↵ jports) {
    struct record *record = malloc(sizeof(struct record));
    record->width = w;
50     record->height = h;
    record->bytes = w * h * 3;
    record->buffer = malloc(record->bytes);
    snprintf(record->header, 62, "P6\n%d %d 255\n", w, h);
    record->header[63] = 0;
55     const char *vfmt = "ppmtoy4m -v0 -S444 -F25:1 2>'tmp/record.ppm.log' | ffmpeg ↵
        ↵ -loglevel 0 -f yuv4mpegpipe -i pipe:- -ac 2 -f jack -i record -target ↵
        ↵ pal-dvd -shortest 'fractal-channel-hopping-%Y-%m-%d.%H-%M-%S_%z.mpeg' >'↵
        ↵ tmp/record.ffmpeg.log' 2>&1";
    int vlen = strlen(vfmt) + 64;
    char *vcmd = malloc(vlen);
    time_t t = time(NULL);
    struct tm tm;
60     localtime_r(&t, &tm);
    if (0 == strftime(vcmd, vlen, vfmt, &tm)) {
        return 0;
    }
    record->jclient = jclient;
65     record->jport [0] = jports [0];

```

```

    record->jport[1] = jports[1];
    record->ppm = popen(vcmd, "w");
    record->pfifo = pfifo_create(record_writer, record);
    return record;
70 }

void record_frame(struct record *record) {
    glReadPixels(0, 0, record->width, record->height, GL_RGB, GL_UNSIGNED_BYTE, ↵
        ↵ record->buffer);
    pfifo_enqueue(record->pfifo, record->bytes, record->buffer);
75 }

void record_stop(struct record *record) {
    pfifo_destroy(record->pfifo);
    pclose(record->ppm);
80 free(record->buffer);
    free(record);
}

```

22 src/record.h

```

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fractal-channel-hopping -- infinite fractal television zoom
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*/

#ifndef RECORD_H
20 #define RECORD_H 1

#include <stdio.h>

#include <jack/jack.h>
25 #include "pfifo.h"

struct record {
    int width;
30 int height;
    int bytes;
    unsigned char *buffer;
    char header[64];
    FILE *ppm;
35 FILE *wav;
    struct pfifo *pfifo;
}

```

```

    jack_client_t *jclient;
    jack_port_t *jport[2];
};
40 struct record *record_start(int w, int h, jack_client_t *jclient, jack_port_t **
    ↵ jports);
void record_frame(struct record *record);
void record_stop(struct record *record);
45 #endif

```

23 src/s2c.sh

```

#!/bin/bash
# fractal-channel-hopping -- infinite fractal television zoom
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echo "/* machine-generated file, do not edit */"
echo "static const char *$1 ="
sed 's|^"|'|' |
20 sed 's|$|\n"|'
echo ";"

```

24 src/yuv2rgb.frag

```

/*
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*/
#version 130

```

```

20 uniform sampler2D y;
uniform sampler2D u;
uniform sampler2D v;

25 void main(void) {
    const mat4 m = mat4(
        1.1643828125, 0.0, 1.59602734375, -0.87078515625,
        1.1643828125, -0.39176171875, -0.81296875, 0.52959375,
        1.1643828125, 2.017234375, 0.0, -1.081390625,
30     0.0, 0.0, 0.0, 1.0
    );
    vec2 p = gl_TexCoord[0].xy;
    vec3 yuv = vec3(texture(y, p).r, texture(u, p).r, texture(v, p).r);
    gl_FragData[0] = vec4(yuv, 1.0) * m;
35 }

```

25 start.sh

```

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#
S="$(dirname "$(readlink -f "$0")")"
FCH="$S/src/fractal-channel-hopping"
20 CHANNELS=(Channel*)
make -C "$S/src" &&
mkdir -p tmp &&
for c in "${CHANNELS[@]}"
do
25   rm -f "tmp/${c}.fifo"
   mkfifo "tmp/${c}.fifo"
done &&
"$FCH" "${CHANNELS[@]}"

```