rdex-client

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Contents

1 ARCHITECTURE.dot

```
digraph G {
  // textures
  node [shape=box,style=filled,fillcolor=lightgrey];
  balls;
  balls1024;
  balls1024h;
  balls512;
  balls512h;
  balls256;
  balls256h;
  balls128;
  balls128h;
  balls64;
  balls64h;
  balls32;
  glowingBalls;
  // shaders
  node [shape=parallelogram,style=filled,fillcolor=lightblue];
  highpass;
  blurH1;
  blurH2;
  blurH3;
  blurH4;
  blurH5;
  blurV1;
  blurV2;
  blurV3;
  blurV4;
```

```
    blurV5;
    wsum;
    // edges
    balls -> highpass ->
    balls1024 -> blurH1 -> balls1024h -> blurV1 ->
    balls512  -> blurH2 -> balls512h  -> blurV2 ->
    balls256  -> blurH3 -> balls256h  -> blurV3 ->
    balls128  -> blurH4 -> balls128h  -> blurV4 ->
    balls64   -> blurH5 -> balls64h   -> blurV5 ->
    balls32;
    balls1024 -> wsum;
    balls512  -> wsum;
    balls256  -> wsum;
    balls128  -> wsum;
    balls64   -> wsum;
    balls32   -> wsum;
    wsum -> glowingBalls;
};
```

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```

3 dvd.xml

```
<dvdauthor>
<vmgm/>
<titleset><menus/><titles>
<pgc>
5 <vob file="hour.mpeg" chapters⇙
    ↳ ="00:00,05:00,10:00,15:00,20:00,25:00,30:00,35:00,40:00,45:00,50:00,55:00,1:00:00"⇙
    ↳ />
<post>jump chapter 1;</post>
</pgc>
</titles></titleset>
</dvdauthor>
```

4 .gitignore

```
*~
*.o
*.frag.c
*.vert.c
5 session
src/cursor.bin
src/cursor.c
src/interleave31
src/interleave31_1024
10 src/rdex
*.mpeg
*.ogv
*.m2v
*.mp2
15 *.mkv
*.mp4
*.raw
*.wav
-/
```

5 RDEX.desktop

```
#!/usr/bin/env xdg-open

[Desktop Entry]
Encoding=UTF-8
5 Version=1.0
Type=Application
```

```
Exec=/home/claude/code/rdex/client/start.sh
Name=RDEX
Comment=Reaction Diffusion Explorer
Icon=/home/claude/code/rdex/client/RDEX.png
```

6 rdex.jr

(application/gzip; charset=binary)

7 RDEX.png

8 README

```
rdex -- reaction-diffusion explorer
==========================================

What Is This All About?
-----------------------

A kind of continuous non-linear cellular automaton, based on solution of
partial differential equations representing chemistry of two reagents
involving reaction and diffusion:

    dU/dt = ru * L(U) - U*V*V + f * (1 - U)
    dV/dt = rv * L(V) + U*V*V - (f + k) * V

where:

    L(x) = Laplacian operator
    ru   = diffusion parameter for U
    rv   = diffusion parameter for V
    f    = some coupling parameter
    l    = another coupling parameter
```

```
This gives a 4D parameter space:

    p = (ru, rv, f, k)

What rdex does is to explore this parameter space to try and find the
"interesting" values.  It labels each point (in 4D space) as follows:

    uniform => the reaction decays into uninteresting flatness
    stable  => the reaction decays into a static pattern
    dynamic => the reaction seems to have an ever changing pattern
    erratic => the numerical process blew up

rdex explores the space completely at random, but spends more time
on more "interesting" points in the parameter space.


Viewing 4D
----------

In 3D homogeneous coordinates:

    M_proj = | 2n/(r-l)   0       (r+l)/(r-l)       0       |
             |   0      2n/(t-b) (t+b)/(t-b)       0       |
             |   0        0      (n+f)/(n-f) (2nf)/(n-f)  |
             |   0        0          -1            0       |
        where
            l = left     r = right
            t = top      b = bottom
            n = near     f = far

    P_obj  = ((original point in object space).xyz, 1)

    P_clip = M_proj * M_view * M_model * P_obj

    P_view = P_clip.xyz / P_clip.w

    draw when -1 < P_view.c < 1 for all c in xyz

In 4D homogeneous coordinates:

    M_proj = | 2n/(r-l)   0         0       (r+l)/(r-l)       0       |
             |   0      2n/(t-b)    0       (t+b)/(t-b)       0       |
             |   0        0       2n/(i-j) (i+j)/(i-j)       0       |
             |   0        0         0      (n+f)/(n-f) (2nf)/(n-f)  |
             |   0        0         0          -1            0       |
        where
            l = left     r = right
            t = top      b = bottom
            i = above    j = below
            n = near     f = far

    P_obj  = ((original point in object space).xyzw, 1)

    P_clip = M_proj * M_view * M_model * P_obj

    P_view = P_clip.xyzw / P_clip.h
```

```
    draw when -1 < P_view.c < 1 for all c in xyzw
80
Hardware Requirements
---------------------

85  * Faster GPU preferred
  * GLSL fragment shader support


Software Requirements
90  ---------------------

  * Linux (maybe works on other OS's too)
  * C compiler (gcc), bash shell, sed
  * OpenGL development files: GL/GLU/GLUT/GLEW
95  * X11 development files: Xpm
  * CURL development files
  * Accelerated 3D drivers


100 Usage
-----

Warning: rdex visual output can consist of rapidly strobing bright
colour patterns, if you are sensitive to them then be careful or don't
105 run rdex at all.

  $ make -C src                                          # build the program
  $ export RDEX_SESSION="/path/to/folder"                # where to store data
  $ export RDEX_UPLOAD="http://host/to/upload/to" # if upload desired
110 $ unset RDEX_UPLOAD                                  # if no upload desired
  $ ./src/rdex                                           # run the program

See rdex-server documentation for the correct value for RDEX_UPLOAD.

115
Tested Machines
---------------

Machine #1
120   * Intel(R) Pentium(R) M processor 1.60GHz
  * ATI Technologies Inc RV350 [Mobility Radeon 9600 M10]
  * GNU/Linux | Debian/Lenny | puredyne
  * "evilblob" fglrx driver supporting OpenGL 2.1.7769
  * gcc (Debian 4.3.2-1) 4.3.2
125
Machine #2
  * Intel(R) Core(TM)2 Duo CPU P7550 2.26GHz
  * nVidia Corporation G98M [GeForce G 105M] (rev a1)
  * GNU/Linux | Ubuntu/Karmic prerelease
130 * "evilblob" nvidia driver supporting OpenGL 3.2.0
  * gcc version 4.4.1 (Ubuntu 4.4.1-4ubuntu8)

Test reports (whether succesful or not) are very welcome!
```

```
Benchmarks
----------

rdex-client-0.beta on machine #2

--8<--
    360172 seconds elapsed
    17145469 frames rendered (47.603559 fps)
    74388 species analyzed (0.206535 sps)
         88.78% uniform
          2.80% stable
          0.87% dynamic
          7.55% erratic
--8<--
real    6002m53.508s
user    795m50.752s
sys     66m12.448s
--8<--
Note: timing may be off by an hour due to daylight savings time change

rdex-client-0.svn1543 on machine #2

--8<--
     14912 seconds elapsed (+/- 1)
    882935 frames rendered (59.209697 fps)
     11785 frames dropped (+/- 60)
      2996 species analyzed (0.200912 sps)
         89.72% uniform
          1.84% stable
          1.90% dynamic
          6.54% erratic
--8<--


Legal
-----

rdex -- reaction-diffusion explorer
Copyright (C) 2008-2017  Claude Heiland-Allen <claude@mathr.co.uk>

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rdex contains portions of code derived from FIRE:
```

```
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Credits
-------

Thanks to Laruft for finding two bugs and testing!


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```

9 setup.sh

```
#!/bin/bash
chgrp audio /dev/hpet
```

```
for i in 0 1
do
  echo "performance" > "/sys/devices/system/cpu/cpu${i}/cpufreq/scaling_governor"
done
cat "/data/cm/rdex/session/"* > /dev/null
```

10 src/arithmeticmean.c

```
/* ================================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------------
Arithmetic Mean Shader
================================================================================ */

#include <math.h>
#include "util.h"
#include "arithmeticmean.h"
#include "arithmeticmean.frag.c"

//==============================================================================
// arithmetic mean shader initialization
struct arithmeticmean *arithmeticmean_init(
  struct arithmeticmean *arithmeticmean
) {
  if (! arithmeticmean) { return 0; }
  if (! shader_init(
          &arithmeticmean->shader, 0, arithmeticmean_frag
     )) {
    return 0;
  }
  shader_uniform(arithmeticmean, texture);
  shader_uniform(arithmeticmean, dx);
  shader_uniform(arithmeticmean, dy);
  arithmeticmean->value.texture = 0;
  arithmeticmean->value.dx = 0;
  arithmeticmean->value.dy = 0;
  glGenTextures(arithmeticmean_tex_max, arithmeticmean->textures);
  glEnable(GL_TEXTURE_2D);
  for (int i = 0; i < arithmeticmean_tex_max; ++i) {
    glBindTexture(GL_TEXTURE_2D, arithmeticmean->textures[i]);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  }
  glDisable(GL_TEXTURE_2D);
  arithmeticmean->result[0] = 0;
  arithmeticmean->result[1] = 0;
  arithmeticmean->result[2] = 0;
  arithmeticmean->result[3] = 0;
  arithmeticmean->stddev = 0;
  return arithmeticmean;
}

//==============================================================================
// arithmetic mean shader reshape callback
void arithmeticmean_reshape(
```

```
  struct arithmeticmean *arithmeticmean, int w, int h
) {
  int w2 = roundtwo(w);
  int h2 = roundtwo(h);
  int d = w2>h2 ? w2 : h2;
  arithmeticmean->count = logtwo(d);
  glEnable(GL_TEXTURE_2D);
  for (int i = 0; i < arithmeticmean->count; ++i) {
    glBindTexture(GL_TEXTURE_2D, arithmeticmean->textures[i]);
    glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB,
      1<<i, 1<<i, 0, GL_RGBA, GL_FLOAT, 0
    );
  }
  glDisable(GL_TEXTURE_2D);
}

//=============================================================
// arithmetic mean display callback
void arithmeticmean_display(
  struct arithmeticmean *arithmeticmean, GLuint fbo, GLuint texture
) {
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, texture);
//  glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
  glUseProgramObjectARB(arithmeticmean->shader.program);
  for (int i = arithmeticmean->count - 1; i >= 0; --i) {
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0, 1, 0, 1);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    glViewport(0, 0, 1<<i, 1<<i);
    glFramebufferTexture2DEXT(
      GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
      arithmeticmean->textures[i], 0
    );
    arithmeticmean->value.dx = 0.5 / (1 << i);
    arithmeticmean->value.dy = 0.5 / (1 << i);
    shader_updatei(arithmeticmean, texture);
    shader_updatef(arithmeticmean, dx);
    shader_updatef(arithmeticmean, dy);
    glBegin(GL_QUADS); { glColor4f(1,1,1,1);
      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();
    glBindTexture(GL_TEXTURE_2D, arithmeticmean->textures[i]);
  }
  glGetTexImage(
    GL_TEXTURE_2D, 0, GL_RGBA, GL_FLOAT, &arithmeticmean->result
  );
  glUseProgramObjectARB(0);
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
  glDisable(GL_TEXTURE_2D);
}

```

```
//=============================================================================
// arithmetic mean idle callback
void arithmeticmean_idle(struct arithmeticmean *arithmeticmean) {
  arithmeticmean->stddev =
    sqrt(arithmeticmean->result[1]
       - arithmeticmean->result[0] * arithmeticmean->result[0]) +
    sqrt(arithmeticmean->result[3]
       - arithmeticmean->result[2] * arithmeticmean->result[2]);
  if (isnan(arithmeticmean->stddev)) { arithmeticmean->stddev = 0; }
}

// EOF
```

11 src/arithmeticmean.frag

```
/* ============================================================================
rdex -- reaction-diffusion explorer
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============================================================================ */

uniform sampler2D texture; // all four channels considered
uniform float dx;          // horizontal distance between source texels
uniform float dy;          // vertical distance between source texels

void main(void) {
  vec2 p = gl_TexCoord[0].st;
  vec4 x00 = texture2D(texture, p);                // box of 4 texels
  vec4 x01 = texture2D(texture, p + vec2(0.0,dy));
  vec4 x10 = texture2D(texture, p + vec2(dx,0.0));
  vec4 x11 = texture2D(texture, p + vec2(dx,dy));
  gl_FragColor = 0.25*(x00+x01+x10+x11);           // arithmetic mean
}
```

12 src/arithmeticmean.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
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----------------------------------------------------------------------------
Arithmetic Mean Shader
============================================================================ */

#ifndef ARITHMETIC_MEAN_H
#define ARITHMETIC_MEAN_H 1

#include "shader.h"

//=============================================================================
// maximum number of textures to allocate (16 => 65536x65536 max size)
#define arithmeticmean_tex_max 16

//=============================================================================
// arithmetic mean shader data
struct arithmeticmean { struct shader shader;
  struct { GLint texture; GLint dx; GLint dy; } uniform;
  struct { int   texture; float dx; float dy; } value;
```

```
  int count;
  GLuint textures[arithmeticmean_tex_max];
  GLfloat result[4];
  float stddev;
};

//============================================================================
// prototypes
struct arithmeticmean *arithmeticmean_init(
  struct arithmeticmean *arithmeticmean
);
void arithmeticmean_reshape(
  struct arithmeticmean *arithmeticmean, int w, int h
);
void arithmeticmean_display(
  struct arithmeticmean *arithmeticmean, GLuint fbo, GLuint texture
);
void arithmeticmean_idle(struct arithmeticmean *arithmeticmean);

#endif
```

13 src/audio.c

```
/* ===========================================================================
rdex -- reaction-diffusion explorer
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---------------------------------------------------------------------------
Audio output
=========================================================================== */

#include <math.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <GL/glew.h>
#include <unistd.h>
#include <fcntl.h>
#include <sys/ioctl.h>
#include <sys/soundcard.h>
#include "audio.h"
#include "audio.frag.c"

volatile char audio_read  = AUDIO_BUFFERS / 2;
volatile char audio_write = 0;
volatile char audio_reset = 1;

void audio_compute(struct audio *audio, jack_default_audio_sample_t **out, ↙
    ↳ jack_nframes_t nframes) {
  /* copy buffers to JACK */
  for (int i = 0; i < nframes; ++i) {
    int r = audio_read;
    for (int c = 0; c < AUDIO_CHANNELS; ++c) {
      // DC blocker
      switch (audio->state) {
        case audio_state_prepare:
          audio->sample[c] = 0;
          audio->iphase[c] = 0.0;
```

```
            out[c][i] = 0.0;
            break;
          case audio_state_intro: {
            double hz = 1000;
            double sr = audio->sr ? audio->sr : 48000;
            double incr = 6.283185307179586 * hz / sr;
            audio->iphase[c] = fmod(audio->iphase[c] + incr, 6.283185307179586);
            out[c][i] = sin(audio->iphase[c]) / 10;
            audio->sample[c]++;
            break;
          }
          case audio_state_outro: {
            int loop = audio->size - 3.0 * audio->sphase;
            int j = audio->index + audio->sphase * 4.0 * (rand()/((double) RAND_MAX) - 0.5);
            j %= loop;
            if (j < 0) { j += loop; }
            jack_default_audio_sample_t xn = audio->buffer[r][c][j];
            audio->yn1[0][c] = xn - audio->xn1[0][c] + audio->r[0][c] * audio->yn1[0][c];
            audio->xn1[0][c] = xn;
            out[c][i] = audio->yn1[0][c];
            break;
          }
          case audio_state_idle: {
            jack_default_audio_sample_t xn = 0;
            audio->yn1[0][c] = xn - audio->xn1[0][c] + audio->r[0][c] * audio->yn1[0][c];
            audio->xn1[0][c] = xn;
            out[c][i] = 0;
            break;
          }
          case audio_state_rolling: {
            jack_default_audio_sample_t xn = audio->buffer[r][c][audio->index];
            audio->yn1[0][c] = xn - audio->xn1[0][c] + audio->r[0][c] * audio->yn1[0][c];
            audio->xn1[0][c] = xn;
            jack_default_audio_sample_t g = fmax(0, 1 - 1 / (1 + (audio->sphase - 2) / 10));
            out[c][i] = g * audio->yn1[0][c];
            break;
          }
        }
      }
      /* increment/wrap read counter, and swap buffers */
      ++audio->index;
      while (audio->index >= audio->size) {
        audio->index -= audio->size;
        int audio_read2 = (r + 1) % AUDIO_BUFFERS;
        // don't overtake write pointer
        if (audio_read2 == audio_write) {
          audio_read2 = (audio_read2 - 1 + AUDIO_BUFFERS) % AUDIO_BUFFERS;
        }
        audio_read = audio_read2;
      }
    }
    // update state
```

```
  audio->sphase += nframes / (double) audio->sr;
  switch (audio->state) {
    case audio_state_prepare:
      if (! (audio->sphase < 2)) {
        audio->state = audio_state_intro;
        audio->sphase = 0;
      }
      break;
    case audio_state_intro:
#if 0
      if (! (audio->sphase < 5)) {
        audio->state = audio_state_rolling;
        audio->sphase = 0;
      }
#endif
      audio->sphase = 0;
      break;
    case audio_state_outro:
      if (! (audio->sphase < 60)) {
        audio->state = audio_state_idle;
        audio->sphase = 0;
/*
        if (! audio->nrt) {
          jack_transport_stop(audio->client);
        }
*/
      }
      break;
    default:
      break;
  }
}

/* JACK audio processing callback */
static int audio_process(jack_nframes_t nframes, void *arg) {
  struct audio *audio = arg;
  /* get JACK buffers */
  jack_default_audio_sample_t *out[2];
  out[0] = (jack_default_audio_sample_t *)
    jack_port_get_buffer(audio->port[0], nframes);
  out[1] = (jack_default_audio_sample_t *)
    jack_port_get_buffer(audio->port[1], nframes);
  audio_compute(audio, out, nframes);
  return 0;
}

static void *audio_process_oss(void *arg) {
  struct audio *audio = arg;
  const char *device = "/dev/dsp1";
  int audio_fd;
  if ((audio_fd = open(device, O_WRONLY, 0)) == -1) {
    perror(device);
    return 0;
  }
  // buffering
  int buffering = (AUDIO_BUFFERS << 16) | 8; // fragment size 2^8 = 256
  if (ioctl(audio_fd, SNDCTL_DSP_SETFRAGMENT, &buffering)) {
```

```
    perror("SNDCTL_DSP_SETFRAGMENT");
    return 0;
  }
  // int16_t
  int format = AFMT_S16_NE;
  if (ioctl(audio_fd, SNDCTL_DSP_SETFMT, &format) == -1) {
    perror("SNDCTL_DSP_SETFMT");
    return 0;
  }
  if (format != AFMT_S16_LE) {
    fprintf(stderr, "BAD OSS FORMAT %d != %d\n", format, AFMT_S16_NE);
    return 0;
  }
  // stereo
  int stereo = 1;
  if (ioctl(audio_fd, SNDCTL_DSP_STEREO, &stereo) == -1) {
    perror("SNDCTL_DSP_STEREO");
    return 0;
  }
  if (stereo != 1) {
    fprintf(stderr, "BAD OSS STEREO %d != 1\n", stereo);
    return 0;
  }
  // sample rate
  int speed = audio->sr;
  if (ioctl(audio_fd, SNDCTL_DSP_SPEED, &speed) == -1) {
    perror("SNDCTL_DSP_SPEED");
    return 0;
  }
  if (speed != audio->sr) {
    fprintf(stderr, "BAD OSS SPEED %d != %d\n", speed, (int) audio->sr);
    return 0;
  }
  // loop
  jack_default_audio_sample_t *out[2] = { &audio->oss_jack_buffer[0][0], &audio
      ↪ ->oss_jack_buffer[1][0] };
  const int nframes = audio->size / 2;
  while (audio->running) {
    audio_compute(audio, out, nframes);
    for (int i = 0; i < nframes; ++i) {
      for (int c = 0; c < 2; ++c) {
        audio->oss_buffer[i][c] = 32767 * fmin(fmax(audio->oss_jack_buffer[c][i
            ↪ ], -1), 1);
      }
    }
    if (write(audio_fd, &audio->oss_buffer[0][0], nframes * 2 * sizeof(int16_t))
        ↪ == -1) {
      perror("audio write");
      //exit(1);
    }
  }
  return 0;
}

void audio_start_oss(struct audio *audio) {
  pthread_create(&audio->oss_thread, 0, audio_process_oss, audio);
}
```

```
/* JACK sample rate callback */
static int audio_srate(jack_nframes_t sr, void *arg) {
  struct audio *audio = arg;
  audio->sr = sr;
  audio->size = 240; // FIXME hardcoded
  fprintf(stderr, "JACK sample rate: %d\n", sr);
  return 0;
}

/* JACK error callback */
static void audio_error(const char *desc) {
  fprintf(stderr, "JACK error: %s\n", desc);
}

/* JACK shutdown callback */
static void audio_shutdown(void *arg) {
  fprintf(stderr, "JACK shutdown\n");
}

/* JACK timebase callback */
static void audio_timebase(jack_transport_state_t state, jack_nframes_t nframes,↙
    ↪ jack_position_t *pos, int new_pos, void *arg) {
  //struct audio *audio = arg;
  if (new_pos || audio_reset) {
    pos->valid = JackPositionBBT;
    pos->beats_per_bar = 4;
    pos->beat_type = 0.25;
    pos->ticks_per_beat = 1920;
    pos->beats_per_minute = 120;
    audio_reset = 0;
    pos->bar = 1;
    pos->beat = 1;
    pos->tick = 0;
    pos->bar_start_tick = (pos->bar - 1) * pos->beats_per_bar * pos->↙
        ↪ ticks_per_beat;
  } else {
    pos->tick +=nframes * pos->ticks_per_beat * pos->beats_per_minute / (pos->↙
        ↪ frame_rate * 60);
    while (pos->tick >= pos->ticks_per_beat) {
      pos->tick -= pos->ticks_per_beat;
      if (++pos->beat > pos->beats_per_bar) {
        pos->beat = 1;
        ++pos->bar;
        pos->bar_start_tick += pos->beats_per_bar * pos->ticks_per_beat;
      }
    }
  }
}

/* exit callback */
void audio_atexit(struct audio *audio) {
  if (audio->nrt) {
    free(audio->nrtbuffers[0]);
    free(audio->nrtbuffers[1]);
    free(audio->nrtbuffers_interleaved);
    sf_close(audio->nrtf);
```

```
  } else {
    audio->running = 0;
    if (0)
      jack_client_close(audio->client);
    if (1)
      pthread_join(audio->oss_thread, 0);
  }
}

//=========================================================
// ...
struct audio *audio_init(struct audio *audio, int nrt) {
  if (! audio) { return 0; }
  if (! shader_init(&audio->shader, 0, audio_frag)) {
    return 0;
  }
  shader_uniform(audio, texture);
  shader_uniform(audio, coords);
  audio->value.texture = 0;
  audio->value.coords = 1;
  // pitch
  audio->pitch = 1;
  // scan point
  audio->x = 0;
  audio->y = 0;
  audio->a = 0;
  audio->curve = 40;
  audio->speed = 128;
  audio->dcurve = 0;
  audio->dspeed = 0;
  // time passing
  audio->samples = 0;

  // pixel buffers
  for (int c = 0; c < AUDIO_CHANNELS; ++c) {
    glGenBuffersARB(AUDIO_COUNT, &audio->pbos[c][0]);
    for (int i = 0; i < AUDIO_COUNT; ++i) {
      glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, audio->pbos[c][i]);
      glBufferDataARB(GL_PIXEL_PACK_BUFFER_ARB, audio_tex_size * audio_tex_size ↙
          ↳ * sizeof(GLfloat), 0, GL_STREAM_READ_ARB); // 1 channel
    }
  }
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, 0);

  /* default sample rate */
  audio->sr = 48000;
  audio->size = 240; // FIXME hardcoded...
  //audio->value.size = audio->size;
  glGenTextures(2, &audio->textures[0]);
  glEnable(GL_TEXTURE_2D);
  // output
  glBindTexture(GL_TEXTURE_2D, audio->textures[0]);
  glTexImage2D(
    GL_TEXTURE_2D, 0, GL_RGBA32F_ARB, audio_tex_size, audio_tex_size, 0, GL_RGBA↙
        ↳ ,
    GL_FLOAT, 0
  );
```

```
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  // coordinates
  glBindTexture(GL_TEXTURE_2D, audio->textures[1]);
  glTexImage2D(
    GL_TEXTURE_2D, 0, GL_RGBA32F_ARB, audio_tex_size, audio_tex_size, 0, GL_RGBA,
    GL_FLOAT, 0 // audio->coords
  );
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  glDisable(GL_TEXTURE_2D);
  audio->index = 0;
  /* initialize DC blocking filters */
  for (int c = 0; c < AUDIO_CHANNELS; ++c) {
    for (int d = 0; d < 2; ++d) {
      audio->r[d][c] = 0.995;
      audio->xn1[d][c] = 0;
      audio->yn1[d][c] = 0;
    }
    // initialize compressor/limiter
    audio->gain[c] = 1.0;
  }
  audio->nrt = nrt;
  audio->frame = 0;
  if (audio->nrt) {
//    audio->size = audio->sr / 25;
    audio->nrtbuffers[0] = calloc(1, 8 * audio->size * sizeof(jack_default_audio_sample_t));// FIXME hardcoded
    audio->nrtbuffers[1] = calloc(1, 8 * audio->size * sizeof(jack_default_audio_sample_t));// FIXME hardcoded
    audio->nrtbuffers_interleaved = calloc(1, 2 * 8 * audio->size * sizeof(float));// FIXME hardcoded
    SF_INFO info = { 0, audio->sr, 2, SF_FORMAT_WAV | SF_FORMAT_FLOAT, 0, 0 };
    audio->nrtf = sf_open("audio.wav", SFM_WRITE, &info);
  } else if (1) {
    audio->state = audio_state_idle;
    audio->sphase = 0;
    audio->running = 1;
    audio_start_oss(audio);
  } else {
    /* set up JACK */
    audio->state = audio_state_idle;
    audio->sphase = 0;
    jack_set_error_function(audio_error);
    if (!(audio->client = jack_client_open("rdex", JackNoStartServer | JackUseExactName, 0))) {
      fprintf (stderr, "JACK server not running?\n");
    } else {
      jack_set_process_callback(audio->client, audio_process, audio);
      jack_set_sample_rate_callback(audio->client, audio_srate, audio);
      jack_on_shutdown(audio->client, audio_shutdown, audio);
      /* create ports */
      audio->port[0] = jack_port_register(
        audio->client, "output_1", JACK_DEFAULT_AUDIO_TYPE, JackPortIsOutput, 0
```

```
      );
      audio->port[1] = jack_port_register(
360     audio->client, "output_2", JACK_DEFAULT_AUDIO_TYPE, JackPortIsOutput, 0
      );
      /* activate audio */
      if (jack_activate(audio->client)) {
        fprintf (stderr, "cannot activate JACK client\n");
365   } else {
#if 1
        /* must be activated before connecting JACK ports */
        const char **ports;
        if ((ports = jack_get_ports(
370       audio->client, NULL, NULL, JackPortIsPhysical | JackPortIsInput
        ))) {
          /* connect up to two physical playback ports */
          int i = 0;
          while (ports[i] && i < 2) {
375         if (jack_connect(
              audio->client, jack_port_name(audio->port[i]), ports[i]
            )) {
              fprintf(stderr, "cannot connect JACK output port\n");
            }
380         i++;
          }
          free(ports);
        }
#endif
385     /* become timebase master */
        if (jack_set_timebase_callback(audio->client, 0, audio_timebase, audio))↙
            ↳ {
          fprintf(stderr, "cannot become JACK master\n");
        }
      }
390 }
  }
  return audio;
}

395 //===========================================================================
// ...
void audio_display1(struct audio *audio, GLuint fbo, GLuint texture, int iter) {
  { // compute coordinates
    memset(audio->coords, 0, 4 * audio_tex_size * audio_tex_size * sizeof(float)↙
        ↳ );
400 float x  = audio->x;
    float y  = audio->y;
    float a  = audio->a;
    float pi2 = 2.0 * 3.1415926;
    float ds =       audio->speed / 256.0 / 256.0;
405 for (int i = 0; i < audio->size; ++i) {
      audio->curve = audio->pitch + 1.0 * rand() / (double) RAND_MAX;
      float da = pi2 * audio->curve / audio->sr;
      float dx = ds * cosf(a);
      float dy = ds * sinf(a);
410   x += dx;
      y += dy;
      a += da;
```

```
      audio->coords[2 * i + 0] = x;
      audio->coords[2 * i + 1] = y;
    }
    audio->x  = x - floorf(x);
    audio->y  = y - floorf(y);
    audio->a  = a - floorf(a/pi2) * pi2;
    audio->samples += audio->size;
  }
  // upload coordinates
  glEnable(GL_TEXTURE_2D);
  glActiveTexture(GL_TEXTURE1);
  glBindTexture(GL_TEXTURE_2D, audio->textures[1]);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB, audio_tex_size, audio_tex_size,↙
      ↳ 0, GL_RG, GL_FLOAT, audio->coords);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  // image
  glActiveTexture(GL_TEXTURE0);
  glBindTexture(GL_TEXTURE_2D, texture);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
  // extract
  glUseProgramObjectARB(audio->shader.program);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  gluOrtho2D(0, 1, 0, 1);
  glMatrixMode(GL_MODELVIEW);
  glLoadIdentity();
  glViewport(0, 0, audio_tex_size, audio_tex_size);
  glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT,↙
      ↳ GL_TEXTURE_2D, audio->textures[0], 0);
  shader_updatei (audio, texture);
  shader_updatei (audio, coords);
  glBegin(GL_QUADS); { glColor4f(1,1,1,1);
    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();
  glActiveTexture(GL_TEXTURE1); glBindTexture(GL_TEXTURE_2D, 0);
  glActiveTexture(GL_TEXTURE0); glBindTexture(GL_TEXTURE_2D, 0);
  glUseProgramObjectARB(0);
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
  // copy texture to PBO
  glBindTexture(GL_TEXTURE_2D, audio->textures[0]);
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, audio->pbos[0][iter]);
  glGetTexImage(GL_TEXTURE_2D, 0, GL_RED,   GL_FLOAT, 0); // async
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, audio->pbos[1][iter]);
  glGetTexImage(GL_TEXTURE_2D, 0, GL_GREEN, GL_FLOAT, 0); // async
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, 0);
  glBindTexture(GL_TEXTURE_2D, 0);
}

void audio_display2(struct audio *audio) {
```

```
  // copy pixel buffers
  for (int i = 0; i < AUDIO_COUNT; ++i) { // FIXME hardcoded
    int w = audio_write;
    for (int c = 0; c < AUDIO_CHANNELS; ++c) {
      glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, audio->pbos[c][i]);
      float *p = glMapBufferARB(GL_PIXEL_PACK_BUFFER_ARB, GL_READ_ONLY_ARB);
      if (p) {
        memcpy(&audio->buffer[w][c][0], p, audio->size * sizeof(float));
        if (! glUnmapBufferARB(GL_PIXEL_PACK_BUFFER_ARB)) {
          fprintf(stderr, "unmap buffer error\n");
        }
      } else {
        memset(&audio->buffer[w][c][0], 0, audio->size * sizeof(float));
      }
    }
    // don't overtake read pointer
    int audio_write2 = (w + 1) % AUDIO_BUFFERS;
    if (audio_write2 == audio_read) {
      audio_write2 = (audio_write2 - 1 + AUDIO_BUFFERS) % AUDIO_BUFFERS;
    }
    audio_write = audio_write2;
  }
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, 0);
  // non-realtime fun
#if 1
  if (audio->nrt) {
    int rate = 1;
    int fps = 25;
    int frame = audio->frame;
    int period = 60 * 60 * fps * rate; // 60 minutes
    int interval = 5 * 60 * fps * rate; // 5 minutes
    if ((frame % rate) == 0 && (frame % period) < interval) {
      audio_compute(audio, audio->nrtbuffers, 8 * audio->size); // FIXME ↙
          ↳ hardcoded
      for (int i = 0; i < 8 * audio->size; ++i) { // FIXME hardcoded
        for (int c = 0; c < 2; ++c) {
          audio->nrtbuffers_interleaved[i*2+c] = audio->nrtbuffers[c][i];
        }
      }
      sf_write_float(audio->nrtf, &audio->nrtbuffers_interleaved[0], 2 * 8 * ↙
          ↳ audio->size);// FIXME hardcoded
    } else if (frame % period == interval) {
      sf_write_sync(audio->nrtf);
    }
  }
#endif
  audio->frame++;
}

void audio_start(struct audio *audio) {
  switch (audio->state) {
    case audio_state_idle:
      audio->state = audio_state_intro;
      audio->sphase = 0;
      if (0)
        jack_transport_start(audio->client);
      break;
```

```
    default:
      break;
  }
}

void audio_stop(struct audio *audio) {
  switch (audio->state) {
    case audio_state_rolling:
      audio->state = audio_state_outro;
      audio->sphase = 0;
      break;
    default:
      break;
  }
}

// EOF
```

14 src/audio.frag

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Extract from input texture using a coordinate texture
================================================================ */

uniform sampler2D texture;
uniform sampler2D coords;

/*
uniform vec2 texsize;
uniform vec2 center;
uniform float radius;
uniform float size;
*/

void main(void) {
  gl_FragColor = texture2D(texture, texture2D(coords, gl_TexCoord[0].st).rg);
/*
  vec2 p = gl_TexCoord[0].st;
  float k = texsize.x * texsize.y / size;
  float da = 2.0 * 3.1415926 / size;
  float a = (p.y + p.x / texsize.x) * 2.0 * 3.1415926 * k;
  vec4 c = vec4(0.0, 0.0, 0.0, 0.0);
  vec2 q;
  q = center + radius * vec2(cos(a), sin(a));
  c += texture2D(texture, q);
  a += da;
  q = center + radius * vec2(cos(a), sin(a));
  c += texture2D(texture, q);
  gl_FragColor = c * 0.5;
*/
}
```

15 src/audio.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010,2019  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Audio output
============================================================================ */

#ifndef AUDIO_H
#define AUDIO_H 1

#include <stdio.h>
#include <pthread.h>
#include <jack/jack.h>
#include <sndfile.h>
#include "shader.h"

//============================================================================
// audio state

#define AUDIO_BUFFERS 64
#define AUDIO_CHANNELS 2
#define audio_tex_size 16
#define AUDIO_BUFSIZE (audio_tex_size * audio_tex_size)
#define AUDIO_COUNT 8

// synchronise between JACK dsp callback and GLUT timer callback
// JACK is the master clock
extern volatile char audio_read;
extern volatile char audio_write;

struct audio { struct shader shader;
  struct { GLint texture, coords; /*texsize, center, radius, size;*/ } uniform;
  struct { GLint texture, coords; /*GLfloat texsize[2], center[2], radius, size
      ↳ ;*/ } value;
  GLuint textures[2];
  float coords[4 * audio_tex_size * audio_tex_size];
  double pitch; // frequency in Hz
  double x, y, a; // scan point
  double curve, speed, dcurve, dspeed; // scan movement
  double samples; // total samples scanned
  GLuint pbos[AUDIO_CHANNELS][AUDIO_COUNT]; // pixel buffers for reading back
      ↳ from GPU (FIXME hardcoded count)

  /* non-realtime mode */
  int nrt;
  int frame;
  jack_default_audio_sample_t *nrtbuffers[2];
  float *nrtbuffers_interleaved;
  SNDFILE *nrtf;
  /* OSS handles */
  int running;
  pthread_t oss_thread;
  int oss_fd;
  int16_t oss_buffer[AUDIO_BUFSIZE][AUDIO_CHANNELS];
  jack_default_audio_sample_t oss_jack_buffer[AUDIO_CHANNELS][AUDIO_BUFSIZE];
  /* JACK handles */
  jack_client_t *client;
```

```
  jack_port_t *port[2];
  enum {
    audio_state_idle,
    audio_state_prepare,
    audio_state_intro,
    audio_state_rolling,
    audio_state_outro
  } state;
  double sphase;
  /* audio buffers */
  unsigned int index;
  jack_default_audio_sample_t buffer[AUDIO_BUFFERS][AUDIO_CHANNELS][AUDIO_BUFSIZE];
  int size;
  int sr;
  /* DC blocker filters */
  jack_default_audio_sample_t r[2][AUDIO_CHANNELS], xn1[2][AUDIO_CHANNELS], yn1[2][AUDIO_CHANNELS], gain[AUDIO_CHANNELS];
  /* intro */
  double iphase[AUDIO_CHANNELS];
  jack_nframes_t sample[AUDIO_CHANNELS];
};

//=============================================================================
// prototypes
struct audio *audio_init(struct audio *audio, int nrt);
void audio_atexit(struct audio *audio);
void audio_display1(struct audio *audio, GLuint fbo, GLuint texture, int iter);
void audio_display2(struct audio *audio);
void audio_start(struct audio *audio);
void audio_stop(struct audio *audio);

#endif
```

16 src/background.c

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Background processing
============================================================================ */

#include <stdlib.h>
#include <string.h>
#include <curl/curl.h>
#include "background.h"
#include "histogram.h"
#include "image.h"
#include "rdex.h"
#include "segment.h"
#include "tamura.h"

//=============================================================================
// upload
#define UPLOAD_DATA_STRLEN 32
#define UPLOAD_DATA_PPMLEN (1024 + rdex_tex_size * rdex_tex_size * 3)
```

```
struct background_upload {
  char ru                [UPLOAD_DATA_STRLEN];
  char rv                [UPLOAD_DATA_STRLEN];
  char f                 [UPLOAD_DATA_STRLEN];
  char k                 [UPLOAD_DATA_STRLEN];
  char behaviour         [UPLOAD_DATA_STRLEN];
  char coarseness_u      [UPLOAD_DATA_STRLEN];
  char contrast_u        [UPLOAD_DATA_STRLEN];
  char directionality_u  [UPLOAD_DATA_STRLEN];
  char coarseness_v      [UPLOAD_DATA_STRLEN];
  char contrast_v        [UPLOAD_DATA_STRLEN];
  char directionality_v  [UPLOAD_DATA_STRLEN];
  char histogram[HISTOGRAM_BUCKETS][HISTOGRAM_BUCKETS][HISTOGRAM_BUCKETS][UPLOAD_DATA_STRLEN];
  char segment[SEGMENT_BUCKETS][UPLOAD_DATA_STRLEN];
  char ppm               [UPLOAD_DATA_PPMLEN];
  int  ppm_bytes;
};

//=============================================================================
// background processing data
struct background_data {
  float ru; float rv; float f; float k; float score; const char *behaviour;
//  char *thumb_ppm; int thumb_ppm_bytes; // must be freed by background thread
  char *full_ppm; int full_ppm_bytes; // must be freed by background thread
  struct image *raw_image; // must be freed by background thread
  struct image *full_image; // must be freed by background thread
};

//=============================================================================
// prototypes
void background_background(struct background *, size_t, struct background_data *);

//=============================================================================
// initialise uploader
struct background *background_init(struct background *background, const char *session) {
  CURLcode c = curl_global_init(CURL_GLOBAL_ALL);
  if (c) { return 0; }
  background->session = session;
  background->url = getenv("RDEX_UPLOAD");
  background->queue = pfifo_create((pfifo_consumer *) background_background, background);
  tamura_init(&background->tamura, rdex_tex_size, rdex_tex_size); //FIXME
  return background;
}

//=============================================================================
// clean up uploader
void background_atexit(struct background *background) {
  curl_global_cleanup();
}

//=============================================================================
// prepare background processing
void background_enqueue(
```

```
75    struct background *background,
      float ru, float rv, float f, float k, float score, const char *behaviour,
//    char *thumb_ppm, int thumb_ppm_bytes, // must be freed by background thread
      char *full_ppm, int full_ppm_bytes,  // must be freed by background thread
      struct image *raw_image, // must be freed by background thread
80    struct image *full_image // must be freed by background thread
    ) {
      struct background_data data;
      data.ru = ru;
      data.rv = rv;
85    data.f = f;
      data.k = k;
      data.score = score;
      data.behaviour = behaviour;
//    data.thumb_ppm = thumb_ppm;
90  //  data.thumb_ppm_bytes = thumb_ppm_bytes;
      data.full_ppm = full_ppm;
      data.full_ppm_bytes = full_ppm_bytes;
      data.raw_image = raw_image;
      data.full_image = full_image;
95    pfifo_enqueue(background->queue, sizeof(struct background_data), &data);
    }

    //=============================================================================
    // do background processing
100 void background_background(
      struct background *background,
      size_t size,
      struct background_data *data
    ) {
105   { // save image
        char filename[1024];
        snprintf(
          filename, 1000,
          "%s/ru_%f__rv_%f__f_%f__k_%f__s_%f.ppm",  // FIXME ensure same stem
110       background->session, data->ru, data->rv, data->f, data->k, data->score
        );
        FILE *imgfile = fopen(filename, "wb");
        if (imgfile) {
          fwrite(data->full_ppm, data->full_ppm_bytes, 1, imgfile);
115       fclose(imgfile);
        }
      } // save thumbnail

      if (background->url) { // upload
120     // image analysis
        struct tamura_features feature[2];
        struct histogram histogram;
        struct segment segment;
        tamura_calculate(&background->tamura, &feature[0], data->raw_image);
125     histogram_calc(&histogram, data->full_image);
        segment_calc(&segment, data->full_image);
        struct background_upload up;
        snprintf(up.ru,                UPLOAD_DATA_STRLEN, "%f", data->ru);
        snprintf(up.rv,                UPLOAD_DATA_STRLEN, "%f", data->rv);
130     snprintf(up.f,                 UPLOAD_DATA_STRLEN, "%f", data->f);
        snprintf(up.k,                 UPLOAD_DATA_STRLEN, "%f", data->k);
```

```
    snprintf(up.behaviour,          UPLOAD_DATA_STRLEN, "%s", data->behaviour);
    snprintf(up.coarseness_u,       UPLOAD_DATA_STRLEN, "%f", feature[0].↙
        ↳ coarseness);
    snprintf(up.contrast_u,         UPLOAD_DATA_STRLEN, "%f", feature[0].contrast)↙
        ↳ ;
    snprintf(up.directionality_u, UPLOAD_DATA_STRLEN, "%f", feature[0].↙
        ↳ directionality);
    snprintf(up.coarseness_v,       UPLOAD_DATA_STRLEN, "%f", feature[1].↙
        ↳ coarseness);
    snprintf(up.contrast_v,         UPLOAD_DATA_STRLEN, "%f", feature[1].contrast)↙
        ↳ ;
    snprintf(up.directionality_v, UPLOAD_DATA_STRLEN, "%f", feature[1].↙
        ↳ directionality);
    for (int r = 0; r < HISTOGRAM_BUCKETS; ++r) {
    for (int g = 0; g < HISTOGRAM_BUCKETS; ++g) {
    for (int b = 0; b < HISTOGRAM_BUCKETS; ++b) {
      snprintf(up.histogram[r][g][b], UPLOAD_DATA_STRLEN, "%f", histogram.bucket↙
          ↳ [r][g][b]);
    }
    }
    }
    for (int s = 0; s < SEGMENT_BUCKETS; ++s) {
      snprintf(up.segment[s], UPLOAD_DATA_STRLEN, "%f", segment.bucket[s]);
    }
    struct curl_httppost *formpost = NULL;
    struct curl_httppost *lastptr = NULL;
#define FORM(s) curl_formadd(&formpost, &lastptr, CURLFORM_COPYNAME, #s, ↙
    ↳ CURLFORM_COPYCONTENTS, up . s, CURLFORM_END)
    FORM(ru);
    FORM(rv);
    FORM(f);
    FORM(k);
    FORM(behaviour);
    FORM(coarseness_u);
    FORM(contrast_u);
    FORM(directionality_u);
    FORM(coarseness_v);
    FORM(contrast_v);
    FORM(directionality_v);
#undef FORM
    for (int r = 0; r < HISTOGRAM_BUCKETS; ++r) {
    for (int g = 0; g < HISTOGRAM_BUCKETS; ++g) {
    for (int b = 0; b < HISTOGRAM_BUCKETS; ++b) {
      char hist[UPLOAD_DATA_STRLEN];
      snprintf(hist, UPLOAD_DATA_STRLEN, "hist_%d_%d_%d", r, g, b);
      curl_formadd(
        &formpost, &lastptr,
        CURLFORM_COPYNAME, hist,
        CURLFORM_COPYCONTENTS, up.histogram[r][g][b],
        CURLFORM_END
      );
    }
    }
    }
    for (int s = 0; s < SEGMENT_BUCKETS; ++s) {
      char seg[UPLOAD_DATA_STRLEN];
      snprintf(seg, UPLOAD_DATA_STRLEN, "seg_%d", s);
```

```
      curl_formadd(
        &formpost, &lastptr,
        CURLFORM_COPYNAME, seg,
        CURLFORM_COPYCONTENTS, up.segment[s],
        CURLFORM_END
      );
    }
    curl_formadd(
      &formpost, &lastptr,
      CURLFORM_COPYNAME, "image",
      CURLFORM_BUFFER, "rdex.ppm",
      CURLFORM_BUFFERPTR, data->full_ppm,
      CURLFORM_BUFFERLENGTH, data->full_ppm_bytes,
      CURLFORM_END
    );
    curl_formadd(
      &formpost, &lastptr,
      CURLFORM_COPYNAME, "submit",
      CURLFORM_COPYCONTENTS, "submit",
      CURLFORM_END
    );
    CURL *curl = curl_easy_init();
    if (curl) {
      curl_easy_setopt(curl, CURLOPT_URL, background->url);
      curl_easy_setopt(curl, CURLOPT_HTTPPOST, formpost);
      curl_easy_setopt(curl, CURLOPT_WRITEDATA, stderr);
      curl_easy_perform(curl);
      curl_easy_cleanup(curl);
      curl_formfree(formpost);
    }
  } // upload

  { // cleanup
//    free(data->thumb_ppm);
    free(data->full_ppm);
    image_free(data->raw_image);
    image_free(data->full_image);
  } // cleanup

}

// EOF
```

17 src/background.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Background processing
============================================================================ */

#ifndef BACKGROUND_H
#define BACKGROUND_H 1

#include "image.h"
#include "histogram.h"
```

```
#include "segment.h"
#include "tamura.h"
#include "pfifo.h"

//=============================================================
// background state
struct background {
  const char *session;
  char *url;
  struct tamura tamura;
  struct pfifo *queue;
};

//=============================================================
// prototypes
struct background *background_init(struct background *background, const char *session);
void background_atexit(struct background *background);
void background_enqueue(
  struct background *background,
  float ru, float rv, float f, float k, float score, const char *behaviour,
//  char *thumb_ppm, int thumb_ppm_bytes, // must be freed by background thread
  char *full_ppm, int full_ppm_bytes,  // must be freed by background thread
  struct image *raw_image, // must be freed by background thread
  struct image *full_image // must be freed by background thread
);

#endif
```

18 src/bloom.c

```
/* =============================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
-------------------------------------------------------------
Bloom/Glow Effect
============================================================= */

#include "util.h"
#include "bloom.h"
#include "bloom.frag.c"

//=============================================================
// initialization
struct bloom *bloom_init(struct bloom *bloom) {
  if (! bloom) { return 0; }
  if (! gblur_init(&bloom->gblur)) { return 0; }
  if (! shader_init(&bloom->shader, 0, bloom_frag)) { return 0; }
  shader_uniform(bloom, tex0);
  shader_uniform(bloom, tex1);
  shader_uniform(bloom, tex2);
  shader_uniform(bloom, tex3);
  shader_uniform(bloom, tex4);
  shader_uniform(bloom, tex5);
  shader_uniform(bloom, tex6);
  shader_uniform(bloom, tex7);
  bloom->value.tex0 = 0;
```

```
  bloom->value.tex1 = 1;
  bloom->value.tex2 = 2;
  bloom->value.tex3 = 3;
  bloom->value.tex4 = 4;
  bloom->value.tex5 = 5;
  bloom->value.tex6 = 6;
  bloom->value.tex7 = 7;
  return bloom;
}

//=========================================================
// reshape callback
void bloom_reshape(struct bloom *bloom, int w, int h) {
  gblur_reshape(&bloom->gblur, w, h);
}

//=========================================================
// display callback
void bloom_display(struct bloom *bloom, GLuint fbo, GLuint texture) {
  // generate blurred copies
  gblur_display(&bloom->gblur, fbo, texture);
  // combine them (back into the input texture)
  glEnable(GL_TEXTURE_2D);
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
  glViewport(0, 0, 1<<bloom->gblur.count, 1<<bloom->gblur.count);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  gluOrtho2D(0, 1, 0, 1);
  glMatrixMode(GL_MODELVIEW);
  glLoadIdentity();
  glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↙
      ↳ GL_TEXTURE_2D, texture, 0);
  glActiveTexture(GL_TEXTURE7); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 7]);
  glActiveTexture(GL_TEXTURE6); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 6]);
  glActiveTexture(GL_TEXTURE5); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 5]);
  glActiveTexture(GL_TEXTURE4); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 4]);
  glActiveTexture(GL_TEXTURE3); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 3]);
  glActiveTexture(GL_TEXTURE2); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 2]);
  glActiveTexture(GL_TEXTURE1); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 1]);
  glActiveTexture(GL_TEXTURE0); glBindTexture(GL_TEXTURE_2D, bloom->gblur.↙
      ↳ textures[0][bloom->gblur.count - 0]);
  glUseProgramObjectARB(bloom->shader.program);
  shader_updatei(bloom, tex0);
  shader_updatei(bloom, tex1);
  shader_updatei(bloom, tex2);
  shader_updatei(bloom, tex3);
  shader_updatei(bloom, tex4);
  shader_updatei(bloom, tex5);
  shader_updatei(bloom, tex6);
  shader_updatei(bloom, tex7);
```

```
75    glBegin(GL_QUADS); { glColor4f(1,1,1,1);
        glTexCoord2f(0, 0); glVertex2f(0, 0);
        glTexCoord2f(1, 0); glVertex2f(1, 0);
        glTexCoord2f(1, 1); glVertex2f(1, 1);
        glTexCoord2f(0, 1); glVertex2f(0, 1);
80    } glEnd();
      // clean up
      glUseProgramObjectARB(0);
      //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
      glActiveTexture(GL_TEXTURE7); glBindTexture(GL_TEXTURE_2D, 0);
85    glActiveTexture(GL_TEXTURE6); glBindTexture(GL_TEXTURE_2D, 0);
      glActiveTexture(GL_TEXTURE5); glBindTexture(GL_TEXTURE_2D, 0);
      glActiveTexture(GL_TEXTURE4); glBindTexture(GL_TEXTURE_2D, 0);
      glActiveTexture(GL_TEXTURE3); glBindTexture(GL_TEXTURE_2D, 0);
      glActiveTexture(GL_TEXTURE2); glBindTexture(GL_TEXTURE_2D, 0);
90    glActiveTexture(GL_TEXTURE1); glBindTexture(GL_TEXTURE_2D, 0);
      glActiveTexture(GL_TEXTURE0); glBindTexture(GL_TEXTURE_2D, 0);
      glDisable(GL_TEXTURE_2D);
    }

95  // EOF
```

19 src/bloom.frag

```
    /* ================================================================
    rdex -- reaction-diffusion explorer
    Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
    ----------------------------------------------------------------
 5  Bloom/Glow effect
    ================================================================ */

    uniform sampler2D tex0;
    uniform sampler2D tex1;
10  uniform sampler2D tex2;
    uniform sampler2D tex3;
    uniform sampler2D tex4;
    uniform sampler2D tex5;
    uniform sampler2D tex6;
15  uniform sampler2D tex7;

    void main(void) {
      //float size;
      //vec2 p0, p1, dp;
20    vec2 p = gl_TexCoord[0].st;
      //vec4 o, o0;
    /* // waaaaaaay too big for most hardware :(
      size = 1024.0; // FIXME hardcoded
      p0 = floor(p * size) / size;
25    p1 = p0 + vec2(1.0, 1.0) / size;
      dp = (p1 - p0) * size;
      o0 = mix(mix(texture2D(tex0, p0), texture2D(tex0, vec2(p1.x, p0.y)), dp.x),
               mix(texture2D(tex0, vec2(p0.x, p1.y)), texture2D(tex0, p1), dp.x), dp
                   ↳ .y);
      o = o0 * 9.0;
30
      size *= 0.5;
      p0 = floor(p * size) / size;
```

```
    p1 = p0 + vec2(1.0, 1.0) / size;
    dp = (p1 - p0) * size;
    o += mix(mix(texture2D(tex1, p0), texture2D(tex1, vec2(p1.x, p0.y)), dp.x),
             mix(texture2D(tex1, vec2(p0.x, p1.y)), texture2D(tex1, p1), dp.x), dp.y);

    size *= 0.5;
    p0 = floor(p * size) / size;
    p1 = p0 + vec2(1.0, 1.0) / size;
    dp = (p1 - p0) * size;
    o += mix(mix(texture2D(tex2, p0), texture2D(tex2, vec2(p1.x, p0.y)), dp.x),
             mix(texture2D(tex2, vec2(p0.x, p1.y)), texture2D(tex2, p1), dp.x), dp.y);

    size *= 0.5;
    p0 = floor(p * size) / size;
    p1 = p0 + vec2(1.0, 1.0) / size;
    dp = (p1 - p0) * size;
    o += mix(mix(texture2D(tex3, p0), texture2D(tex3, vec2(p1.x, p0.y)), dp.x),
             mix(texture2D(tex3, vec2(p0.x, p1.y)), texture2D(tex3, p1), dp.x), dp.y);

    size *= 0.5;
    p0 = floor(p * size) / size;
    p1 = p0 + vec2(1.0, 1.0) / size;
    dp = (p1 - p0) * size;
    o += mix(mix(texture2D(tex4, p0), texture2D(tex4, vec2(p1.x, p0.y)), dp.x),
             mix(texture2D(tex4, vec2(p0.x, p1.y)), texture2D(tex4, p1), dp.x), dp.y);

    size *= 0.5;
    p0 = floor(p * size) / size;
    p1 = p0 + vec2(1.0, 1.0) / size;
    dp = (p1 - p0) * size;
    o += mix(mix(texture2D(tex5, p0), texture2D(tex5, vec2(p1.x, p0.y)), dp.x),
             mix(texture2D(tex5, vec2(p0.x, p1.y)), texture2D(tex5, p1), dp.x), dp.y);

    size *= 0.5;
    p0 = floor(p * size) / size;
    p1 = p0 + vec2(1.0, 1.0) / size;
    dp = (p1 - p0) * size;
    o += mix(mix(texture2D(tex6, p0), texture2D(tex6, vec2(p1.x, p0.y)), dp.x),
             mix(texture2D(tex6, vec2(p0.x, p1.y)), texture2D(tex6, p1), dp.x), dp.y);

    size *= 0.5;
    p0 = floor(p * size) / size;
    p1 = p0 + vec2(1.0, 1.0) / size;
    dp = (p1 - p0) * size;
    o += mix(mix(texture2D(tex7, p0), texture2D(tex7, vec2(p1.x, p0.y)), dp.x),
             mix(texture2D(tex7, vec2(p0.x, p1.y)), texture2D(tex7, p1), dp.x), dp.y);
*/
    vec4 o0 = texture2D(tex0, p);
    vec4 o1 = texture2D(tex1, p);
    vec4 o2 = texture2D(tex2, p);
```

```
  vec4 o3 = texture2D(tex3, p);
  vec4 o4 = texture2D(tex4, p);
  vec4 o5 = texture2D(tex5, p);
  vec4 o6 = texture2D(tex6, p);
  vec4 o7 = texture2D(tex7, p);
  vec4 o;
  float k = 1.1;
  float t = 1.0;
  o  = o7; o *= k; t *= k;
  o += o6; o *= k; t += 1.0; t *= k;
  o += o5; o *= k; t += 1.0; t *= k;
  o += o4; o *= k; t += 1.0; t *= k;
  o += o3; o *= k; t += 1.0; t *= k;
  o += o2; o *= k; t += 1.0; t *= k;
  o += o1; o *= k; t += 1.0; t *= k;
  o += o0; o *= k; t += 1.0; t *= k;
  o /= t;
  float l = length(o.rgb);
  gl_FragColor = vec4(o.rgb * clamp(log(5.0 * log(5.0 * l + 1.0) + 1.0), 0.0, ↙
      ↪ 1.0), 1.0);
}
```

20 src/bloom.h

```
/* ==========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------
Bloom/Glow Effect
========================================================================== */

#ifndef BLOOM_H
#define BLOOM_H 1

#include "shader.h"
#include "gblur.h"

//============================================================================
// shader data
struct bloom { struct shader shader;
  struct { GLint tex0, tex1, tex2, tex3, tex4, tex5, tex6, tex7; } uniform;
  struct { int   tex0, tex1, tex2, tex3, tex4, tex5, tex6, tex7; } value;
  struct gblur gblur;
};

//============================================================================
// prototypes
struct bloom *bloom_init(struct bloom *bloom);
void bloom_reshape(struct bloom *bloom, int w, int h);
void bloom_display(struct bloom *bloom, GLuint fbo, GLuint texture);

#endif
```

21 src/blur.c

```
/* ==========================================================================
```

```
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
-------------------------------------------------------------------------------
Blur shader
=============================================================================== */

#include "blur.h"
#include "blur.frag.c"

//=============================================================================
// blur shader initialization
struct blur *blur_init(struct blur *blur) {
  if (! blur) { return 0; }
  if (! shader_init(&blur->shader, 0, blur_frag)) { return 0; }
  shader_uniform(blur, texture);
  shader_uniform(blur, d);
  blur->value.texture = 0;
  blur->value.d[0] = 0;
  blur->value.d[1] = 0;
  return blur;
}

// EOF
```

22 src/blur.frag

```
/* =============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
============================================================================= */

uniform sampler2D texture;
uniform vec2 d;

void main(void) {
  vec2 p = gl_TexCoord[0].st;
  vec4 x00 = texture2D(texture, p);
  vec4 x01 = texture2D(texture, p + vec2(0.0,d.y));
  vec4 x10 = texture2D(texture, p + vec2(d.x,0.0));
  vec4 x11 = texture2D(texture, p + vec2(d.x,d.y));
  vec2 p0 = floor(p / d) * d;
  vec2 dp = (p - p0) / d;
  vec3 tl = texture2D(texture, p0).rgb;
  vec3 tr = texture2D(texture, p0 + vec2(d.x, 0.0)).rgb;
  vec3 bl = texture2D(texture, p0 + vec2(0.0, d.y)).rgb;
  vec3 br = texture2D(texture, p0 + vec2(d.x, d.y)).rgb;
  vec3 t = tl * (1.0 - dp.x) + dp.x * tr;
  vec3 b = bl * (1.0 - dp.x) + dp.x * br;
  vec3 l = tl * (1.0 - dp.y) + dp.y * bl;
  vec3 r = tr * (1.0 - dp.y) + dp.y * br;
  vec3 m1 = t * (1.0 - dp.y) + dp.y * b;
  vec3 m2 = l * (1.0 - dp.x) + dp.x * r;
  vec3 m = 0.5 * (m1 + m2);
  gl_FragColor = vec4(m, 1.0);
}
```

23 src/blur.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Blur shader
================================================================ */

#ifndef BLUR_H
#define BLUR_H 1

#include "shader.h"

//================================================================
// arithmetic mean shader data
struct blur { struct shader shader;
  struct { GLint texture; GLint d; } uniform;
  struct { int   texture; float d[2]; } value;
};

//================================================================
// prototypes
struct blur *blur_init(struct blur *blur);

#endif
```

24 src/borderwindow.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Border/Window Shader
================================================================ */

#include "borderwindow.h"
#include "borderwindow.frag.c"
#include "projection.vert.c"
#include "borderwindow_pick.frag.c"
#include "projection_pick.vert.c"

//================================================================
// borderwindow shader initialization
struct borderwindow *borderwindow_init(struct borderwindow *borderwindow) {
  if (! borderwindow) { return 0; }
  if (! shader_init(&borderwindow->shader, projection_vert, borderwindow_frag)) ↙
      ↳ {
    return 0;
  }
  // vertex shader
  shader_uniform(borderwindow, origin);
  shader_uniform(borderwindow, scale);
  shader_uniform(borderwindow, rotate);
  shader_uniform(borderwindow, translate);
  shader_uniform(borderwindow, near);
```

```
  shader_uniform(borderwindow, far);
  borderwindow->value.origin[0] = 0.15;
  borderwindow->value.origin[1] = 0.15;
  borderwindow->value.origin[2] = 0.05;
  borderwindow->value.origin[3] = 0.05;
  borderwindow->value.scale[0] = 1.0/0.15;
  borderwindow->value.scale[1] = 1.0/0.15;
  borderwindow->value.scale[2] = 1.0/0.05;
  borderwindow->value.scale[3] = 1.0/0.05;
  int k = 0;
  for (int i = 0; i < 4; ++i) {
  for (int j = 0; j < 4; ++j) {
    borderwindow->value.rotate[k++] = i == j;
  }}
  borderwindow->value.translate[0] = 0.0;
  borderwindow->value.translate[1] = 0.0;
  borderwindow->value.translate[2] = 0.0;
  borderwindow->value.translate[3] = 8.0;
  borderwindow->value.near[0] = -1.0;
  borderwindow->value.near[1] = -1.0;
  borderwindow->value.near[2] = -1.0;
  borderwindow->value.near[3] =  4.0;
  borderwindow->value.far[0] =  1.0;
  borderwindow->value.far[1] =  1.0;
  borderwindow->value.far[2] =  1.0;
  borderwindow->value.far[3] = 12.0;
  // fragment shader
  shader_uniform(borderwindow, texture);
  shader_uniform(borderwindow, pack);
  shader_uniform(borderwindow, size);
  borderwindow->value.texture = 0;
  borderwindow->value.pack = 0;
  return borderwindow;
}

//=========================================================================
// borderwindow shader activation
void borderwindow_use(struct borderwindow *borderwindow) {
  if (borderwindow) {
    glUseProgramObjectARB(borderwindow->shader.program);
    borderwindow->attr.delta = glGetAttribLocationARB(borderwindow->shader.↙
        ↳ program, "delta");
    borderwindow->attr.spin  = glGetAttribLocationARB(borderwindow->shader.↙
        ↳ program, "spin");
    borderwindow->attr.pick  = glGetAttribLocationARB(borderwindow->shader.↙
        ↳ program, "pick");
    // vertex shader
    shader_updatef4(borderwindow, origin);
    shader_updatef4(borderwindow, scale);
    shader_updatem4(borderwindow, rotate);
    shader_updatef4(borderwindow, translate);
    shader_updatef4(borderwindow, near);
    shader_updatef4(borderwindow, far);
    // fragment shader
    shader_updatei (borderwindow, texture);
    shader_updatef (borderwindow, pack);
    shader_updatef (borderwindow, size);
```

```
  } else {
    glUseProgramObjectARB(0);
  }
}

//============================================================
// borderwindow picking shader initialization
struct borderwindow_pick *borderwindow_pick_init(struct borderwindow_pick *borderwindow_pick) {
  if (! borderwindow_pick) { return 0; }
  if (! shader_init(&borderwindow_pick->shader, projection_pick_vert, borderwindow_pick_frag)) {
    return 0;
  }
  // vertex shader
  shader_uniform(borderwindow_pick, origin);
  shader_uniform(borderwindow_pick, scale);
  shader_uniform(borderwindow_pick, rotate);
  shader_uniform(borderwindow_pick, translate);
  shader_uniform(borderwindow_pick, near);
  shader_uniform(borderwindow_pick, far);
  borderwindow_pick->value.origin[0] = 0.15;
  borderwindow_pick->value.origin[1] = 0.15;
  borderwindow_pick->value.origin[2] = 0.05;
  borderwindow_pick->value.origin[3] = 0.05;
  borderwindow_pick->value.scale[0] = 1.0/0.15;
  borderwindow_pick->value.scale[1] = 1.0/0.15;
  borderwindow_pick->value.scale[2] = 1.0/0.05;
  borderwindow_pick->value.scale[3] = 1.0/0.05;
  int k = 0;
  for (int i = 0; i < 4; ++i) {
  for (int j = 0; j < 4; ++j) {
    borderwindow_pick->value.rotate[k++] = i == j;
  }}
  borderwindow_pick->value.translate[0] = 0.0;
  borderwindow_pick->value.translate[1] = 0.0;
  borderwindow_pick->value.translate[2] = 0.0;
  borderwindow_pick->value.translate[3] = 8.0;
  borderwindow_pick->value.near[0] = -1.0;
  borderwindow_pick->value.near[1] = -1.0;
  borderwindow_pick->value.near[2] = -1.0;
  borderwindow_pick->value.near[3] =  4.0;
  borderwindow_pick->value.far[0] =  1.0;
  borderwindow_pick->value.far[1] =  1.0;
  borderwindow_pick->value.far[2] =  1.0;
  borderwindow_pick->value.far[3] = 12.0;
  return borderwindow_pick;
}

//============================================================
// borderwindow_pick shader activation
void borderwindow_pick_use(struct borderwindow_pick *borderwindow_pick) {
  if (borderwindow_pick) {
    glUseProgramObjectARB(borderwindow_pick->shader.program);
    borderwindow_pick->attr.delta = glGetAttribLocationARB(borderwindow_pick->shader.program, "delta");
    // vertex shader
```

```
135       shader_updatef4(borderwindow_pick, origin);
          shader_updatef4(borderwindow_pick, scale);
          shader_updatem4(borderwindow_pick, rotate);
          shader_updatef4(borderwindow_pick, translate);
          shader_updatef4(borderwindow_pick, near);
140       shader_updatef4(borderwindow_pick, far);
        } else {
          glUseProgramObjectARB(0);
        }
      }
145
      // EOF
```

25 src/borderwindow.frag

```
      /* ================================================================
      rdex -- reaction-diffusion explorer
      Copyright (C) 2008,2010,2011,2019  Claude Heiland-Allen <claude@mathr.co.uk>
      ----------------------------------------------------------------
  5   Sphere shader
      ================================================================ */

      uniform sampler2DArray tex;

 10   varying vec2 spin2;
      varying float scale2;

      void main(void) {
        float p = gl_TexCoord[0].x;               // float in [0..]
 15     vec2 q0 = gl_TexCoord[0].zw;
        vec2 q1 = 2.0 * (q0 - vec2(0.5, 0.5));
        float d = dot(q1,q1);
        if (d < 1.0) {
          vec3 n = normalize(vec3(q1, sqrt(1.0-d)));
 20       vec2 q = q1 / (1.0 + sqrt(1.0 - d));
          vec2 q2 = scale2 * q + spin2;
          vec2 frac = q2;
          // linear interpolation
          vec3 m = texture(tex, vec3(frac, p)).rgb;
 25       // output
          float a = 1.0;
          float k = gl_FragCoord.z - 0.1 * cos(sqrt(d) * 3.1415926*0.5);
          float c = 0.0625 + pow(dot(vec3(0.0, 0.0, 1.0), n), 2.0);
          vec3 rgb = m * c;
 30       gl_FragDepth = k;
          gl_FragColor = vec4(rgb, a);
        } else {
          discard;
        }
 35   }
```

26 src/borderwindow.h

```
      /* ================================================================
      rdex -- reaction-diffusion explorer
      Copyright (C) 2008,2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
```

```
------------------------------------------------------------------------
Border/Window Shader
============================================================================ */

#ifndef BORDERWINDOW_H
#define BORDERWINDOW_H 1

#include "shader.h"

//============================================================================
// borderwindow shader data
struct borderwindow { struct shader shader;
  struct {
    GLint origin, scale, rotate, translate, near, far; // vertex
    GLint texture, pack, size; // fragment
  } uniform;
  struct {
    float origin[4], scale[4], rotate[16], translate[4], near[4], far[4]; // ↙
        ↳ vertex
    int texture; float pack, size; // fragment
  } value;
  struct {
    GLint delta, spin, pick; // vertex
  } attr;
};

struct borderwindow_pick { struct shader shader;
  struct {
    GLint origin, scale, rotate, translate, near, far; // vertex
  } uniform;
  struct {
    float origin[4], scale[4], rotate[16], translate[4], near[4], far[4]; // ↙
        ↳ vertex
  } value;
  struct {
    GLint delta; // vertex
  } attr;
};

//============================================================================
// prototypes
struct borderwindow *borderwindow_init(struct borderwindow *borderwindow);
void borderwindow_use(struct borderwindow *borderwindow);

struct borderwindow_pick *borderwindow_pick_init(struct borderwindow_pick *↙
    ↳ borderwindow_pick);
void borderwindow_pick_use(struct borderwindow_pick *borderwindow_pick);

#endif
```

27 src/borderwindow_pick.frag

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
------------------------------------------------------------------------
Sphere shader for ball picking
```

```
================================================================================ */

varying float ignore;

void main(void) {
  vec2 p = gl_TexCoord[0].xy;                    // float in [0..1]
  vec2 q0 = gl_TexCoord[0].zw;
  vec2 q1 = 2.0 * (q0 - vec2(0.5, 0.5));
  float d = dot(q1,q1);
  if (ignore < 0.5 && d < 1.0) {
    float k = gl_FragCoord.z - 0.1 * cos(sqrt(d) * 3.1415926*0.5);
    gl_FragDepth = k;
    gl_FragColor = vec4(p, 0.0, 1.0);
  } else {
    discard;
  }
}
```

28 src/camera.c

```
/* ================================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------------
Chase camera
================================================================================ */

/*

The camera is modelled by some point masses connected together:

    T  = target
    V* = vertices of camera cage

where:

    massV* << massT

Each V is connected to T by a stretchy spring of appropriate rest length.
Each V is connected to each other V by a stiff spring of appropriate rest
length.

The camera rotation matrix is:

    C = sum(V*) / count(V*)
    M = normalize([ V0, V1, V2, V3 ] - [ C, C, C, C ])

Updating the view is peformed by updating the mass spring damper model.

*/

#include <math.h>
#include <string.h>
#include "camera.h"

void camera_init(struct camera *camera) {
  memset(camera, 0, sizeof(*camera));
```

```
  camera->dt = 0.004;
  // camera scale
  float r = 1.0 / 16.0;
  // initialize target point
  camera->T.position.v[3] = r;
  camera->T.mass = 1 << 20;
  // initialize camera points
  camera->V[0].position.v[0] = r;
  camera->V[1].position.v[1] = r;
  camera->V[2].position.v[2] = r;
  camera->V[3].position.v[3] = r;
  camera->V[4].position.v[0] = -r;
  camera->V[5].position.v[1] = -r;
  camera->V[6].position.v[2] = -r;
  camera->V[7].position.v[3] = -r;
  camera->r = r;
  for (int i = 0; i < 8; ++i) {
    camera->V[i].mass = 1.0 / 8.0; // + 4.0 * ((i == 3) || (i == 7));
  }
  // initialize external links
  for (int i = 0; i < 8; ++i) {
    camera->TV[i].p = &camera->T;
    camera->TV[i].q = &camera->V[i];
    camera->TV[i].length = vdistance4(&camera->T.position, &camera->V[i].↙
        ↳ position);
    camera->TV[i].k = 1;
    camera->TV[i].c = 2 * sqrt(camera->TV[i].k); // * camera->V[i].mass);
  }
  // initialize internal links
  int k = 0;
  for (int i = 0; i < 8 - 1; ++i) {
    for (int j = i + 1; j < 8; ++j) {
      camera->VV[k].p = &camera->V[i];
      camera->VV[k].q = &camera->V[j];
      camera->VV[k].length = vdistance4(&camera->V[i].position, &camera->V[j].↙
          ↳ position);
      camera->VV[k].k = 1;
      camera->VV[k].c = 2 * sqrt(camera->VV[k].k * sqrt(camera->V[i].mass * ↙
          ↳ camera->V[j].mass));
      k++;
    }
  }
  // reset position
  for (int i = 0; i < 8; ++i) {
    camera->V[i].position.v[3] -= r;
  }
}

void camera_force(struct link *l) {
  struct vec4 zero = { { 0, 0, 0, 0 } };
  struct vec4 f, dir, ndir, dv;
  float ldir, x, v;
  vcopy4(&f, &zero);
  /* dir  = l->p->position - l->q->position
   * ldir = length(dir)
   * ndir = dir / ldir
   * x    = l->length - ldir
```

```
     * v    = dot(l->p->velocity - l->q->velocity, ndir)
     * f    = - (k x + c v)
     */
    vvsub4(&dir, &l->p->position, &l->q->position);
    ldir = vlength4(&dir);
    if (! (ldir > 0)) {
      return;
    }
    x = ldir - l->length;
    vsdiv4(&ndir, &dir, ldir);
    vvsub4(&dv, &l->p->velocity, &l->q->velocity);
    v = vvdot4(&dv, &ndir);
    vsmul4(&f, &ndir, l->k * x + l->c * v);
    vvsub4(&l->p->force, &l->p->force, &f);
    vvadd4(&l->q->force, &l->q->force, &f);
  }

  void camera_action1(struct mass *m, float dt) {
    struct vec4 a, dv;
    vsdiv4(&a, &m->force, m->mass);
    vsmul4(&dv, &a, dt);
    vvadd4(&m->velocity, &m->velocity, &dv);
  }

  void camera_friction(struct mass *m, struct vec4 *v0, struct vec4 *v0dir) {
    struct vec4 dv;
    vvsub4(&dv, &m->velocity, v0);
    vsmul4(&m->velocity, v0, 0.995);
    vvadd4(&m->velocity, &m->velocity, &dv);
  //  vsmul4(&m->velocity, &m->velocity, 0.99);
  }

  void camera_action2(struct mass *m, float dt) {
    struct vec4 dp;
    vsmul4(&dp, &m->velocity, dt);
    vvadd4(&m->position, &m->position, &dp);
  }

  void camera_update(struct camera *camera, struct vec4 *target) {
    // set target
    struct vec4 zero = { { 0, 0, 0, 0 } };
    vvmul4(&camera->T.position, target, &camera->scale);
    vcopy4(&camera->T.velocity, &zero);
    // reset forces
    vcopy4(&camera->T.force, &zero);
    for (int i = 0; i < 8; ++i) {
      vcopy4(&camera->V[i].force, &zero);
    }
    // accumulate forces from links
    for (int i = 0; i < 8; ++i) {
      camera_force(&camera->TV[i]);
    }
    for (int i = 0; i < 28; ++i) {
      camera_force(&camera->VV[i]);
    }
    // convert forces to movement
    for (int i = 0; i < 8; ++i) {
```

```
    camera_action1(&camera->V[i], camera->dt);
  }
  struct vec4 v0, v0dir;
  vcopy4(&v0, &zero);
  for (int i = 0; i < 8; ++i) {
    vvadd4(&v0, &v0, &camera->V[i].velocity);
  }
  vsdiv4(&v0, &v0, 8.0);
  float vl = vlength4(&v0);
  vl = vl > 0 ? vl : 1.0;
  vsdiv4(&v0dir, &v0, vl);
  for (int i = 0; i < 8; ++i) {
    camera_friction(&camera->V[i], &v0, &v0dir);
  }
  for (int i = 0; i < 8; ++i) {
    camera_action2(&camera->V[i], camera->dt);
  }
  // calculate camera center
  vcopy4(&camera->C, &zero);
  for (int i = 0; i < 8; ++i) {
    vvadd4(&camera->C, &camera->C, &camera->V[i].position);
  }
  vsdiv4(&camera->C, &camera->C, 8);
  // calculate camera matrix
  struct vec4 v[8];
  for (int i = 0; i < 8; ++i) {
    vvsub4(&v[i], &camera->V[i].position, &camera->C);
  }
  int k = 0;
  for (int i = 0; i < 4; ++i) {
    float d = vdistance4(&v[i], &v[i+4]);
    for (int j = 0; j < 4; ++j) {
      camera->M.m[k++] = (v[i].v[j] - v[i+4].v[j]) / d; //(n + m);
    }
  }
  vcopy4(&camera->C, &camera->V[3].position);
  vvdiv4(&camera->C, &camera->C, &camera->scale);
}

// EOF
```

29 src/camera.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Chase camera
================================================================ */

#ifndef CAMERA_H
#define CAMERA_H 1

#include "matrix.h"

struct mass {
  struct vec4 position;
```

```
  struct vec4 velocity;
  struct vec4 force;
  float mass;
};

struct link {
  struct mass *p;
  struct mass *q;
  float length;
  float k;
  float c;
};

struct camera {
  struct mass T;
  struct mass V[8];
  struct link TV[8];
  struct link VV[28];
  struct vec4 C;
  struct mat4 M;
  float dt;
  float r;
  struct vec4 scale;
};

void camera_init(struct camera *camera);
void camera_update(struct camera *camera, struct vec4 *target);

#endif
```

30 src/copysquare.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Copy And Square Shader
================================================================ */

#include "util.h"
#include "copysquare.h"
#include "copysquare.frag.c"

//================================================================
// copysquare shader initialization
struct copysquare *copysquare_init(struct copysquare *copysquare) {
  if (! copysquare) { return 0; }
  if (! shader_init(&copysquare->shader, 0, copysquare_frag)) {
    return 0;
  }
  shader_uniform(copysquare, texture);
  copysquare->value.texture = 0;
  glGenTextures(1, &copysquare->texture);
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, copysquare->texture);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
```

```
  glDisable(GL_TEXTURE_2D);
  copysquare->width = 0;
  copysquare->height = 0;
  return copysquare;
}

//=============================================================
// copysquare shader reshape callback
void copysquare_reshape(struct copysquare *copysquare, int w, int h) {
  copysquare->width  = roundtwo(w);
  copysquare->height = roundtwo(h);
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, copysquare->texture);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB,
    copysquare->width, copysquare->height, 0, GL_RGBA, GL_FLOAT, 0
  );
  glDisable(GL_TEXTURE_2D);
}

//=============================================================
// copysquare shader display callback
void copysquare_display(
  struct copysquare *copysquare, GLuint fbo, GLuint texture
) {
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, texture);
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
  glFramebufferTexture2DEXT(
    GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
    copysquare->texture, 0
  );
  glUseProgramObjectARB(copysquare->shader.program);
  shader_updatei(copysquare ,texture);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  gluOrtho2D(0, 1, 0, 1);
  glMatrixMode(GL_MODELVIEW);
  glLoadIdentity();
  glViewport(0, 0, copysquare->width, copysquare->height);
  glBegin(GL_QUADS); { glColor4f(1,1,1,1);
    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);
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
  glDisable(GL_TEXTURE_2D);
}

//=============================================================
// copysquare shader idle callback
void copysquare_idle(struct copysquare *copysquare) { }

// EOF
```

31 src/copysquare.frag

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
================================================================ */

uniform sampler2D texture;                          // (U,V,_,_)

void main(void) {
  vec2 p = gl_TexCoord[0].st;
  vec2 c = texture2D(texture, p).rg;
  gl_FragColor = vec4(c.r,c.r*c.r,c.g,c.g*c.g);     // (U,U^2,V,V^2)
}
```

32 src/copysquare.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Copy And Square Shader
================================================================ */

#ifndef COPYSQUARE_H
#define COPYSQUARE_H 1

#include "shader.h"

//================================================================
// copysquare shader data
struct copysquare { struct shader shader;
  struct { GLint texture; } uniform;
  struct { int   texture; } value;
  GLuint texture;
  int width;
  int height;
};

//================================================================
// prototypes
struct copysquare *copysquare_init(struct copysquare *copysquare);
void copysquare_reshape(struct copysquare *copysquare, int w, int h);
void copysquare_display(
  struct copysquare *copysquare, GLuint fbo, GLuint texture
);
void copysquare_idle(struct copysquare *copysquare);

#endif
```

33 src/difference.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
```

```
5   Difference Shader
    ================================================================== */

    #include "util.h"
    #include "difference.h"
10  #include "difference.frag.c"

    //====================================================================
    // difference shader initialization
    struct difference *difference_init(struct difference *difference) {
15    if (! difference) { return 0; }
      if (! shader_init(&difference->shader, 0, difference_frag)) {
        return 0;
      }
      shader_uniform(difference, texture1);
20    shader_uniform(difference, texture2);
      difference->value.texture1 = 0;
      difference->value.texture2 = 1;
      if (! arithmeticmean_init(&difference->arithmeticmean)) { return 0; }
      glGenTextures(2, difference->textures);
25    glEnable(GL_TEXTURE_2D);
      glBindTexture(GL_TEXTURE_2D, difference->textures[0]);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
      glBindTexture(GL_TEXTURE_2D, difference->textures[1]);
30    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
      glDisable(GL_TEXTURE_2D);
      difference->width = 0;
      difference->height = 0;
35    difference->snap = 0;
      difference->calc = 0;
      difference->mean = 0;
      return difference;
    }
40

    //====================================================================
    // difference shader reshape callback
    void difference_reshape(struct difference *difference, int w, int h) {
      difference->width  = roundtwo(w);
45    difference->height = roundtwo(h);
      glEnable(GL_TEXTURE_2D);
      glBindTexture(GL_TEXTURE_2D, difference->textures[0]);
      glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB,
        difference->width, difference->height, 0, GL_RGBA, GL_FLOAT, 0
50    );
      glBindTexture(GL_TEXTURE_2D, difference->textures[1]);
      glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB,
        difference->width, difference->height, 0, GL_RGBA, GL_FLOAT, 0
      );
55    glDisable(GL_TEXTURE_2D);
      arithmeticmean_reshape(&difference->arithmeticmean, w, h);
    }

    //====================================================================
60  // difference shader display callback
    void difference_display(
```

```
  struct difference *difference, GLuint fbo, GLuint texture
) {
  if (difference->snap) {
    glEnable(GL_TEXTURE_2D);
    glBindTexture(GL_TEXTURE_2D, texture);
    //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
    glFramebufferTexture2DEXT(
      GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
      difference->textures[0], 0
    );
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0, 1, 0, 1);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    glViewport(0, 0, difference->width, difference->height);
    glBegin(GL_QUADS); { glColor4f(1,1,1,1);
      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();
    //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
    glDisable(GL_TEXTURE_2D);
    difference->snap = 0;
  } else if (difference->calc) {
    glEnable(GL_TEXTURE_2D);
    glActiveTexture(GL_TEXTURE1);
    glBindTexture(GL_TEXTURE_2D, texture);
    glActiveTexture(GL_TEXTURE0);
    glBindTexture(GL_TEXTURE_2D, difference->textures[0]);
    //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
    glFramebufferTexture2DEXT(
      GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
      difference->textures[1], 0
    );
    glUseProgramObjectARB(difference->shader.program);
    shader_updatei(difference, texture1);
    shader_updatei(difference, texture2);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0, 1, 0, 1);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    glViewport(0, 0, difference->width, difference->height);
    glBegin(GL_QUADS); { glColor4f(1,1,1,1);
      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);
    //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
    glDisable(GL_TEXTURE_2D);
    arithmeticmean_display(
      &difference->arithmeticmean, fbo, difference->textures[1]
    );
```

```
    difference->mean = difference->arithmeticmean.result[0];
    difference->calc = 0;
  }
}

//=============================================================================
// difference shader idle callback
void difference_idle(struct difference *difference) {
  arithmeticmean_idle(&difference->arithmeticmean);
}

// EOF
```

34 src/difference.frag

```
/* =============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
============================================================================= */

uniform sampler2D texture1;       // first texture
uniform sampler2D texture2;       // second texture

void main(void) {
  vec2 p = gl_TexCoord[0].st;      // texel coordinates
  vec4 d = texture2D(texture1, p)  // difference between channels
         - texture2D(texture2, p);
  float q = sqrt(dot(d,d));        // length of the difference vector
  gl_FragColor = vec4(q, q, q, 1.0); // output
}
```

35 src/difference.h

```
/* =============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
-----------------------------------------------------------------------------
Difference Shader
============================================================================= */

#ifndef DIFFERENCE_H
#define DIFFERENCE_H 1

#include "shader.h"
#include "arithmeticmean.h"

//=============================================================================
// difference shader data
struct difference { struct shader shader;
  struct { GLint texture1; GLint texture2; } uniform;
  struct { int   texture1; GLint texture2; } value;
  struct arithmeticmean arithmeticmean;
  GLuint textures[2];
  int width;
  int height;
  int snap;
```

```
  int calc;
  float mean;
};

//=============================================================================
// prototypes
struct difference *difference_init(struct difference *difference);
void difference_reshape(struct difference *difference, int w, int h);
void difference_display(
  struct difference *difference, GLuint fbo, GLuint texture
);
void difference_idle(struct difference *difference);

#endif
```

36 src/expcolour.c

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Exponential colour space conversion
============================================================================ */

#include "expcolour.h"
#include "expcolour.frag.c"

//=============================================================================
// shader initialization
struct expcolour *expcolour_init(struct expcolour *expcolour) {
  if (! expcolour) { return 0; }
  if (! shader_init(&expcolour->shader, 0, expcolour_frag)) {
    return 0;
  }
  shader_uniform(expcolour, texture);
  expcolour->value.texture = 0;
  return expcolour;
}

// EOF
```

37 src/expcolour.frag

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Exponential colour space conversion
============================================================================ */

uniform sampler2D texture;

void main(void) {
  vec2 p = gl_TexCoord[0].st;
  vec4 x = texture2D(texture, p);
  float l = dot(vec3(0.3, 0.5, 0.2), x.rgb);
```

```
  float a;
  if (l > 0.5) {
    a = 1.0;
  } else {
    a = 0.0;
  }
  if (l > 0.0) {
    x /= l;
    l *= 2.0;
    l = exp(l) / (l + 1.0) * 0.4;
    x *= l;
  }
  gl_FragColor = vec4(x.rgb, a);
}
```

38 src/expcolour.h

```
/* ===========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
---------------------------------------------------------------------------
Exponential colour space conversion
=========================================================================== */

#ifndef EXPCOLOUR_H
#define EXPCOLOUR_H 1

#include "shader.h"

//============================================================================
// shader data
struct expcolour { struct shader shader;
  struct { GLint texture; } uniform;
  struct { int   texture; } value;
};

//============================================================================
// prototypes
struct expcolour *expcolour_init(struct expcolour *expcolour);

#endif
```

39 src/falsecolour.c

```
/* ===========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
---------------------------------------------------------------------------
False Colour Shader
=========================================================================== */

#include "util.h"
#include "falsecolour.h"
#include "falsecolour.frag.c"

//============================================================================
```

```
// false colour shader initialization
struct falsecolour *falsecolour_init(struct falsecolour *falsecolour) {
  if (! falsecolour) { return 0; }
  if (! shader_init(&falsecolour->shader, 0, falsecolour_frag)) {
    return 0;
  }
  if (! blur_init(&falsecolour->blur)) { return 0; }
  shader_uniform(falsecolour, texture);
  falsecolour->value.texture = 0;
  glGenTextures(1, &falsecolour->texture0);
  glGenTextures(1, &falsecolour->texture);
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, falsecolour->texture0);
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  glBindTexture(GL_TEXTURE_2D, falsecolour->texture);
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
//  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  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);
  glDisable(GL_TEXTURE_2D);
  falsecolour->width = 0;
  falsecolour->height = 0;
  return falsecolour;
}

//============================================================
// false colour shader reshape callback
void falsecolour_reshape(
  struct falsecolour *falsecolour, int w, int h
) {
  falsecolour->width  = roundtwo(w);
  falsecolour->height = roundtwo(h);
  falsecolour->blur.value.d[0] = 0.5 / falsecolour->width;
  falsecolour->blur.value.d[1] = 0.5 / falsecolour->height;
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, falsecolour->texture0);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB,
    falsecolour->width * 2, falsecolour->height * 2, 0, GL_RGBA, GL_FLOAT, 0
  );
  glBindTexture(GL_TEXTURE_2D, falsecolour->texture);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB,
    falsecolour->width, falsecolour->height, 0, GL_RGBA, GL_FLOAT, 0
  );
  glBindTexture(GL_TEXTURE_2D, 0);
  glDisable(GL_TEXTURE_2D);
}

//============================================================
// false colour shader display callback
void falsecolour_display(
  struct falsecolour *falsecolour, GLuint fbo, GLuint texture
) {
  glEnable(GL_TEXTURE_2D);
```

```
    glViewport(0, 0, falsecolour->width * 2, falsecolour->height * 2);
    glBindTexture(GL_TEXTURE_2D, texture);
    //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
    glFramebufferTexture2DEXT(
      GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
      falsecolour->texture0, 0
    );
    glUseProgramObjectARB(falsecolour->shader.program);
    shader_updatei(falsecolour, texture);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0, 1, 0, 1);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    glBegin(GL_QUADS); { glColor4f(1,1,1,1);
      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);
    glBindTexture(GL_TEXTURE_2D, 0);
    // linear interpolation
    glViewport(0, 0, falsecolour->width, falsecolour->height);
    glFramebufferTexture2DEXT(
      GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
      falsecolour->texture, 0
    );
    glUseProgramObjectARB(falsecolour->blur.shader.program);
    shader_updatei(&(falsecolour->blur), texture);
    shader_updatef2(&(falsecolour->blur), d);
    glBindTexture(GL_TEXTURE_2D, falsecolour->texture0);
    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    gluOrtho2D(0, 1, 0, 1);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();
    glBegin(GL_QUADS); { glColor4f(1,1,1,1);
      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);
    //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
    glBindTexture(GL_TEXTURE_2D, 0);
    glDisable(GL_TEXTURE_2D);
}

//=============================================================================
// false colour shader idle callback
void falsecolour_idle(struct falsecolour *falsecolour) {
}

// EOF
```

40 src/falsecolour.frag

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010  Claude Heiland-Allen <claude@mathr.co.uk>
================================================================ */

uniform sampler2D texture; // U := r, V := g, other channels ignored

void main(void) {
  const mat3 lcc2rgb = mat3(                    // LC1C2 => RGB
     1.0,  1.407,  0.0,                         // colour space
     1.0, -0.677, -0.236,                       // conversion matrix
     1.0,  0.0,    1.848
  );
  vec2 p = gl_TexCoord[0].st;                   // texel coordinates
  vec2 q;
  float u, v, h, l;
  vec3 c;
  // point to colour
  q = texture2D(texture, p).rg;
  u = 1.0 - q.r;
  v = q.g;
  h = 16.0*atan(v, u);
  l = clamp(cos(16.0*(v*v + u*u)), 0.0, 1.0);
  c = vec3(l, 0.5*cos(h), 0.5*sin(h));
  gl_FragColor = vec4(c * lcc2rgb, 1.0);
}
```

41 src/falsecolour.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
False Colour Shader
================================================================ */

#ifndef FALSECOLOUR_H
#define FALSECOLOUR_H 1

#include "shader.h"
#include "blur.h"

//================================================================
// false colour shader data
struct falsecolour { struct shader shader;
  struct { GLint  texture; } uniform;
  struct { int    texture; } value;
  GLuint texture0, texture;
  int width;
  int height;
  struct blur blur;
};

//================================================================
```

```
// protoypes
struct falsecolour *falsecolour_init(struct falsecolour *falsecolour);
void falsecolour_reshape(
  struct falsecolour *falsecolour, int w, int h
);
void falsecolour_display(
  struct falsecolour *falsecolour, GLuint fbo, GLuint texture
);
void falsecolour_idle(struct falsecolour *falsecolour);

#endif
```

42 src/font.png

43 src/fonts.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Text bitmap fonts
================================================================ */

#include <GL/glew.h>
#include "fonts.h"

extern char _binary_font_rgba_start;

struct fonts *fonts_init(struct fonts *fonts) {
  fonts->size = 512;
  fonts->pack = 8;
  glGenTextures(1, &fonts->texture);
  glBindTexture(GL_TEXTURE_2D, fonts->texture);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
```

```
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, fonts->size, fonts->size, 0, GL_RGBA, ↙
      ↳ GL_UNSIGNED_BYTE, &_binary_font_rgba_start);
  return fonts;
}
```

44 src/fonts.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Text bitmap fonts
================================================================ */

#ifndef FONTS_H
#define FONTS_H 1

#include <GL/glew.h>

struct fonts {
  GLuint texture;
  int size;
  int pack;
};

struct fonts *fonts_init(struct fonts *fonts);

#endif
```

45 src/gblur.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Multi-scale Gaussian Blur
================================================================ */

#include "util.h"
#include "gblur.h"
#include "gblur.frag.c"

//================================================================
// initialization
struct gblur *gblur_init(struct gblur *gblur) {
  if (!gblur) { return 0; }
  if (!shader_init(&gblur->shader, 0, gblur_frag)) {
    return 0;
  }
  if (!expcolour_init(&gblur->expcolour)) {
    return 0;
  }
  shader_uniform(gblur, texture);
  shader_uniform(gblur, d);
  gblur->value.texture = 0;
```

```
25    gblur->value.d[0] = 0;
      gblur->value.d[1] = 0;
      glGenTextures(gblur_tex_max, &gblur->textures[0][0]);
      glGenTextures(gblur_tex_max, &gblur->textures[1][0]);
      glEnable(GL_TEXTURE_2D);
30    for (int i = 0; i < gblur_tex_max; ++i) {
        for (int c = 0; c < 2; ++c) {
          glBindTexture(GL_TEXTURE_2D, gblur->textures[c][i]);
          glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
          glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
35        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, GL_CLAMP);
          glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, GL_CLAMP);
        }
      }
      glDisable(GL_TEXTURE_2D);
40    return gblur;
    }

    //====================================================================
    // reshape callback
45  void gblur_reshape(struct gblur *gblur, int w, int h) {
      // allocate textures
      int w2 = roundtwo(w);
      int h2 = roundtwo(h);
      int d = w2>h2 ? w2 : h2;
50    gblur->count = logtwo(d);
      glEnable(GL_TEXTURE_2D);
      for (int i = 0; i <= gblur->count; ++i) {
        for (int c = 0; c < 2; ++c) {
          glBindTexture(GL_TEXTURE_2D, gblur->textures[c][i]);
55        glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, 1<<i, 1<<i, 0, GL_RGBA, ↙
              ↳ GL_UNSIGNED_BYTE, 0);
          //glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB, 1<<i, 1<<i, 0, GL_RGBA, ↙
              ↳ GL_FLOAT, 0);
        }
      }
      glDisable(GL_TEXTURE_2D);
60  }

    //====================================================================
    // display callback
    void gblur_display(struct gblur *gblur, GLuint fbo, GLuint texture) {
65    // copy texture
      glEnable(GL_TEXTURE_2D);
      glBindTexture(GL_TEXTURE_2D, texture);
      //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
      glMatrixMode(GL_PROJECTION);
70    glLoadIdentity();
      gluOrtho2D(0, 1, 0, 1);
      glMatrixMode(GL_MODELVIEW);
      glLoadIdentity();
      glViewport(0, 0, 1<<gblur->count, 1<<gblur->count);
75    glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↙
          ↳ GL_TEXTURE_2D, gblur->textures[0][gblur->count], 0);
      glUseProgramObjectARB(gblur->expcolour.shader.program);
      shader_updatei(&gblur->expcolour, texture);
      glBegin(GL_QUADS); { glColor4f(1,1,1,1);
```

```
      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();
    // multi-scale blur
    glUseProgramObjectARB(gblur->shader.program);
    for (int i = gblur->count - 1; i >= 0; --i) {
      // blur horizontally
      glBindTexture(GL_TEXTURE_2D, gblur->textures[0][i+1]);
      glMatrixMode(GL_PROJECTION);
      glLoadIdentity();
      gluOrtho2D(0, 1, 0, 1);
      glMatrixMode(GL_MODELVIEW);
      glLoadIdentity();
      glViewport(0, 0, 1<<(i+1), 1<<(i+1));
      glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↙
          ↳ GL_TEXTURE_2D, gblur->textures[1][i+1], 0);
      gblur->value.d[0] = 1.0 / (1<<(i+1));
      gblur->value.d[1] = 0.0;
      shader_updatei(gblur, texture);
      shader_updatef2(gblur, d);
      glBegin(GL_QUADS); { glColor4f(1,1,1,1);
        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();
      // blur vertically (and downscale)
      glBindTexture(GL_TEXTURE_2D, gblur->textures[1][i+1]);
      glMatrixMode(GL_PROJECTION);
      glLoadIdentity();
      gluOrtho2D(0, 1, 0, 1);
      glMatrixMode(GL_MODELVIEW);
      glLoadIdentity();
      glViewport(0, 0, 1<<i, 1<<i);
      glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↙
          ↳ GL_TEXTURE_2D, gblur->textures[0][i], 0);
      gblur->value.d[0] = 0.0;
      gblur->value.d[1] = 1.0 / (1<<(i+1));
      shader_updatei(gblur, texture);
      shader_updatef2(gblur, d);
      glBegin(GL_QUADS); { glColor4f(1,1,1,1);
        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();
    }
    // clean up
    glUseProgramObjectARB(0);
    //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
    glBindTexture(GL_TEXTURE_2D, 0);
    glDisable(GL_TEXTURE_2D);
}

// EOF
```

46 src/gblur.frag

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Separated Gaussian Blur Shader
============================================================================ */

uniform sampler2D texture;
uniform vec2 d;

// weights
const float w0 = 0.402619947, w1 = 0.244201342, w2 = 0.054488685;

void main(void) {
  vec2 p = gl_TexCoord[0].st;
  vec4 o = vec4(0.0, 0.0, 0.0, 0.0);
  o += w2 * texture2D(texture, p - 2.0 * d);
  o += w1 * texture2D(texture, p -       d);
  o += w0 * texture2D(texture, p          );
  o += w1 * texture2D(texture, p +       d);
  o += w2 * texture2D(texture, p + 2.0 * d);
  gl_FragColor = o;
}
```

47 src/gblur.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Multi-scale Gaussian Blur
============================================================================ */

#ifndef GBLUR_H
#define GBLUR_H 1

#include "shader.h"
#include "expcolour.h"

//============================================================================
// maximum number of textures to allocate (16 => 65536x65536 max size)
#define gblur_tex_max 16

//============================================================================
// shader data
struct gblur { struct shader shader;
  struct { GLint texture; GLint d; } uniform;
  struct { int   texture; float d[2]; } value;
  int count;
  // textures[0] is blur output
  // textures[1] is temporary
  GLuint textures[2][gblur_tex_max];
  struct expcolour expcolour;
};
```

```
//============================================================
// prototypes
struct gblur *gblur_init(struct gblur *gblur);
void gblur_reshape(struct gblur *gblur, int w, int h);
void gblur_display(struct gblur *gblur, GLuint fbo, GLuint texture);

#endif
```

48 src/glyph-curve-less.svg

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<svg xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/xlink" width="128" height="128">
<g fill="none" stroke-linecap="round">
 <g stroke="#000000" stroke-width="8">
  <path d="M 16 64 A 48 48 0 1 1 64 112" />
  <path d="M 16 64 A 24 24 0 1 1 40 88" />
 </g>
 <g stroke="#0000ff" stroke-width="4">
  <path d="M 16 64 A 24 24 0 1 1 40 88" />
 </g>
 <g stroke="#ffff00" stroke-width="4">
  <path d="M 16 64 A 48 48 0 1 1 64 112" />
 </g>
 <g stroke="#000000" stroke-width="8">
  <path d="M 88 64 L 40 64 M 72 80 L 88 64 M 72 48 L 88 64" />
 </g>
 <g stroke="#00ff00" stroke-width="4">
  <path d="M 88 64 L 40 64 M 72 80 L 88 64 M 72 48 L 88 64" />
 </g>
</g>
</svg>
```

49 src/glyph-curve-more.svg

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<svg xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/xlink" width="128" height="128">
<g fill="none" stroke-linecap="round">
 <g stroke="#000000" stroke-width="8">
  <path d="M 16 64 A 48 48 0 1 1 64 112" />
  <path d="M 16 64 A 24 24 0 1 1 40 88" />
 </g>
 <g stroke="#0000ff" stroke-width="4">
  <path d="M 16 64 A 48 48 0 1 1 64 112" />
 </g>
 <g stroke="#ffff00" stroke-width="4">
  <path d="M 16 64 A 24 24 0 1 1 40 88" />
 </g>
 <g stroke="#000000" stroke-width="8">
  <path d="M 88 64 L 40 64 M 56 80 L 40 64 M 56 48 L 40 64" />
 </g>
 <g stroke="#00ff00" stroke-width="4">
  <path d="M 88 64 L 40 64 M 56 80 L 40 64 M 56 48 L 40 64" />
 </g>
```

```
</g>
</svg>
```

50 src/glyphs.c

```
/* ========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
------------------------------------------------------------------------
Sequencer glyphs
======================================================================== */

#include <GL/glew.h>
#include "glyphs.h"

extern char _binary_glyph_curve_less_rgba_start;
extern char _binary_glyph_curve_more_rgba_start;
extern char _binary_glyph_speed_less_rgba_start;
extern char _binary_glyph_speed_more_rgba_start;

struct glyphs *glyphs_init(struct glyphs *glyphs) {
  glGenTextures(4, &glyphs->textures[0]);
  // curve less
  glBindTexture(GL_TEXTURE_2D, glyphs->textures[sequence_curve_less]);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, 128, 128, 0, GL_RGBA, GL_UNSIGNED_BYTE↙
      ↳ , &_binary_glyph_curve_less_rgba_start);
  // curve more
  glBindTexture(GL_TEXTURE_2D, glyphs->textures[sequence_curve_more]);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, 128, 128, 0, GL_RGBA, GL_UNSIGNED_BYTE↙
      ↳ , &_binary_glyph_curve_more_rgba_start);
  // speed less
  glBindTexture(GL_TEXTURE_2D, glyphs->textures[sequence_speed_less]);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, 128, 128, 0, GL_RGBA, GL_UNSIGNED_BYTE↙
      ↳ , &_binary_glyph_speed_less_rgba_start);
  // speed more
  glBindTexture(GL_TEXTURE_2D, glyphs->textures[sequence_speed_more]);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, 128, 128, 0, GL_RGBA, GL_UNSIGNED_BYTE↙
      ↳ , &_binary_glyph_speed_more_rgba_start);
  return glyphs;
}
```

51 src/glyphs.h

```
/* ========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
------------------------------------------------------------------------
Sequencer glyphs
```

```
   ═══════════════════════════════════════════════════════════════ */

#ifndef GLYPHS_H
#define GLYPHS_H 1

#include <GL/glew.h>

struct glyphs {
  GLuint textures[4];
};

struct glyphs *glyphs_init(struct glyphs *glyphs);

#define sequence_curve_less 0
#define sequence_curve_more 1
#define sequence_speed_less 2
#define sequence_speed_more 3

#endif
```

52 src/glyph-speed-less.svg

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<svg xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/↙
    ↳ xlink" width="128" height="128">
<g fill="none" stroke-linecap="round">
 <g stroke="#000000" stroke-width="8">
  <path d="M 24 24 L 104 24" />
  <path d="M 40 104 L 88 104" />
 </g>
 <g stroke="#0000ff" stroke-width="4">
  <path d="M 24 24 L 104 24" />
 </g>
 <g stroke="#ffff00" stroke-width="4">
  <path d="M 40 104 L 88 104" />
 </g>
 <g stroke="#000000" stroke-width="8">
  <path d="M 64 88 L 64 40 M 80 72 L 64 88 M 48 72 L 64 88" />
 </g>
 <g stroke="#00ff00" stroke-width="4">
  <path d="M 64 88 L 64 40 M 80 72 L 64 88 M 48 72 L 64 88" />
 </g>
</g>
</svg>
```

53 src/glyph-speed-more.svg

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<svg xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/↙
    ↳ xlink" width="128" height="128">
<g fill="none" stroke-linecap="round">
 <g stroke="#000000" stroke-width="8">
  <path d="M 24 24 L 104 24" />
  <path d="M 40 104 L 88 104" />
 </g>
 <g stroke="#0000ff" stroke-width="4">
```

```
  <path d="M 40 104 L 88 104" />
 </g>
 <g stroke="#ffff00" stroke-width="4">
  <path d="M 24 24 L 104 24" />
 </g>
 <g stroke="#000000" stroke-width="8">
  <path d="M 64 40 L 64 88 M 80 56 L 64 40 M 48 56 L 64 40" />
 </g>
 <g stroke="#00ff00" stroke-width="4">
  <path d="M 64 40 L 64 88 M 80 56 L 64 40 M 48 56 L 64 40" />
 </g>
</g>
</svg>
```

54 src/histogram.c

```
/* ========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2017  Claude Heiland-Allen <claude@mathr.co.uk>
------------------------------------------------------------------------
CPU-Based Image Histograms
======================================================================== */

#include "histogram.h"

void histogram_calc(struct histogram *h, const struct image *i) {
  for (int r = 0; r < HISTOGRAM_BUCKETS; ++r) {
  for (int g = 0; g < HISTOGRAM_BUCKETS; ++g) {
  for (int b = 0; b < HISTOGRAM_BUCKETS; ++b) {
    h->bucket[r][g][b] = 0;
  }
  }
  }
  for (int y = 0; y < i->height; ++y) {
  for (int x = 0; x < i->width; ++x) {
    int r = HISTOGRAM_BUCKETS * I(i,x,y,0);
    int g = HISTOGRAM_BUCKETS * I(i,x,y,1);
    int b = HISTOGRAM_BUCKETS * I(i,x,y,2);
    if (r < 0) r = 0;
    if (r >= HISTOGRAM_BUCKETS) r = HISTOGRAM_BUCKETS - 1;
    if (g < 0) g = 0;
    if (g >= HISTOGRAM_BUCKETS) g = HISTOGRAM_BUCKETS - 1;
    if (b < 0) b = 0;
    if (b >= HISTOGRAM_BUCKETS) b = HISTOGRAM_BUCKETS - 1;
    h->bucket[r][g][b] += 1;
  }
  }
  float pixels = i->width * i->height;
  for (int r = 0; r < HISTOGRAM_BUCKETS; ++r) {
  for (int g = 0; g < HISTOGRAM_BUCKETS; ++g) {
  for (int b = 0; b < HISTOGRAM_BUCKETS; ++b) {
    h->bucket[r][g][b] /= pixels;
  }
  }
  }
}
```

55 src/histogram.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
CPU-Based Image Histograms
============================================================================ */

#ifndef HISTOGRAM_H
#define HISTOGRAM_H 1

#include "image.h"

#define HISTOGRAM_BUCKETS 8
struct histogram {
  float bucket[HISTOGRAM_BUCKETS][HISTOGRAM_BUCKETS][HISTOGRAM_BUCKETS];
};

void histogram_calc(struct histogram * h, const struct image *i);

#endif
```

56 src/image.c

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
CPU-Based Images
============================================================================ */

#include <stdlib.h>
#include <GL/glew.h>
#include "image.h"

struct image *image_alloc(int width, int height, int channels) {
  struct image *image =
    malloc(sizeof(struct image) + width*height*channels*sizeof(float));
  if (! image) { return 0; }
  image->width = width;
  image->height = height;
  image->channels = channels;
  image->data = (float *) (image+1);
  return image;
}

void image_free(struct image *image) {
  free(image);
}

void image_copytexture(struct image *image, GLuint texture) {
  glBindTexture(GL_TEXTURE_2D, texture);
  glGetTexImage(GL_TEXTURE_2D, 0, GL_RGB, GL_FLOAT, image->data); // FIXME check
    ↳ data is big enough for the image!!!!
}
```

57 src/image.h

```
/* ============================================================================
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----------------------------------------------------------------------------
CPU-Based Images
============================================================================ */

#ifndef IMAGE_H
#define IMAGE_H 1

#include <GL/glew.h>

struct image {
  int width;
  int height;
  int channels;
  float *data;
};

#define I(i,x,y,z) ((i)->data[(i)->channels*((i)->width*(y)+(x))+(z)])

struct image *image_alloc(int width, int height, int channels);
void image_free(struct image *image);
void image_copytexture(struct image *image, GLuint texture);

#endif
```

58 src/interleave31.c

```
#include <stdio.h>
#include <stdlib.h>

int main(int argc, char **argv) {
  if (argc != 4) {
    return 1;
  }
  int d = atoi(argv[3]);
  FILE *in3 = fopen(argv[1], "rb");
  if (in3) {
    FILE *in1 = fopen(argv[2], "rb");
    if (in1) {
      for (int i = 0; i < d*d; ++i) {
        putchar(getc(in3));
        putchar(getc(in3));
        putchar(getc(in3));
        putchar(getc(in1));
      }
      fclose(in1);
    } else {
      return 1;
    }
    fclose(in3);
  } else {
    return 1;
```

```
  }
  return 0;
}
```

59 src/intro.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
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----------------------------------------------------------------
Intro module
================================================================ */

#include <math.h>
#include <GL/glew.h>
#include <GL/glut.h>
#include "intro.h"

extern char _binary_intro_image_rgba_start;

struct intro *intro_init(struct intro *intro) {
  glGenTextures(1, &intro->tex);
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, intro->tex);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, INTRO_IMAGE_SIZE, INTRO_IMAGE_SIZE, 0,↙
      ↳ GL_RGBA, GL_UNSIGNED_BYTE, &_binary_intro_image_rgba_start);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glBindTexture(GL_TEXTURE_2D, 0);
  glDisable(GL_TEXTURE_2D);
  intro->state = intro_idle;
  intro->phase = 0;
  return intro;
}

void intro_reshape(struct intro *intro, int w, int h) {
  intro->width = w;
  intro->height = h;
}

void intro_display(struct intro *intro, double dt) { /* FIXME aspect ratio? */
  glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
  switch (intro->state) {
    case intro_idle:
    case intro_active:
      intro->rx = 0;//32.0 * exp(-32.0 * (intro->phase * intro->phase) / (↙
          ↳ INTRO_TIME * INTRO_TIME));
      intro->ry = 0;//32.0 * exp(-16.0 * (intro->phase * intro->phase) / (↙
          ↳ INTRO_TIME * INTRO_TIME));
      glMatrixMode(GL_PROJECTION);
      glLoadIdentity();
      glViewport(0, 0, intro->width, intro->height);
      gluOrtho2D(0, 1, 0, 1);
      glMatrixMode(GL_MODELVIEW);
      glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
      glEnable(GL_TEXTURE_2D);
      glBindTexture(GL_TEXTURE_2D, intro->tex);
```

```
      glBegin(GL_QUADS); {
        glColor4f(1,1,1,1);
        glTexCoord2f(0+intro->rx, 1+intro->ry); glVertex2f(0, 0);
        glTexCoord2f(0+intro->rx, 0+intro->ry); glVertex2f(0, 1);
        glTexCoord2f(1+intro->rx, 0+intro->ry); glVertex2f(1, 1);
        glTexCoord2f(1+intro->rx, 1+intro->ry); glVertex2f(1, 0);
      } glEnd();
      glDisable(GL_TEXTURE_2D);
      if (intro->state == intro_active) {
        intro->phase += dt;
        if (! (intro->phase < INTRO_TIME)) {
          intro->state = intro_done;
          intro->phase = 0;
        }
      }
      break;
    default:
      break;
  }
}

void intro_start(struct intro *intro) {
  if (intro->state == intro_idle) {
    intro->state = intro_active;
    intro->phase = 0;
  }
}
```

60 src/intro.h

```
/* ========================================================================
rdex -- reaction-diffusion explorer
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------------------------------------------------------------------------
Intro module
======================================================================== */

#ifndef INTRO_H
#define INTRO_H 1

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

#define INTRO_TIME 5.0
#define INTRO_IMAGE_SIZE 1024

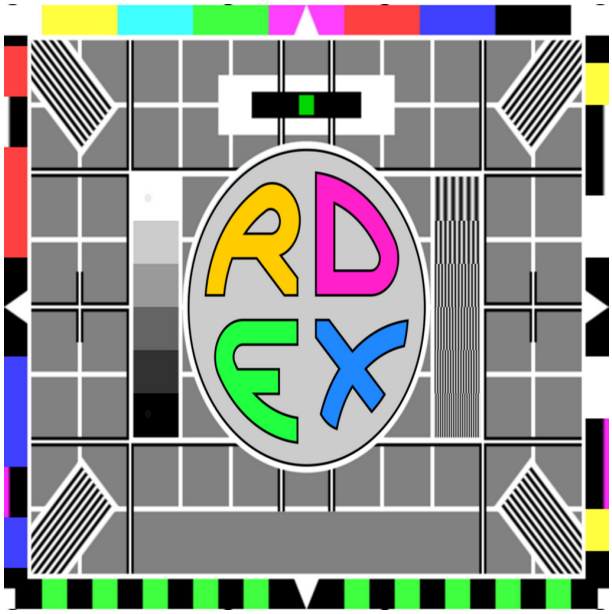
struct intro {
  GLuint tex;
  int width;
  int height;
  enum { intro_idle, intro_active, intro_done } state;
  double phase;
  double rx;
  double ry;
};

struct intro *intro_init(struct intro *intro);
```

```
void intro_reshape(struct intro *intro, int w, int h);
void intro_display(struct intro *intro, double dt);
void intro_start(struct intro *intro);

#endif
```

61 src/intro-image.png



62 src/library.c

```
/* ================================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010,2011,2019  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------------
Library Module
================================================================================ */

#include <assert.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <wordexp.h>
#include <math.h>
#include "library.h"
#include "background.h"
#include "rdex.h"

static void library_copy_texture_to_array(struct library *library, int layer) {
  glBindTexture(GL_TEXTURE_2D, library->texture);
  glBindTexture(GL_TEXTURE_2D_ARRAY, library->texture_array);
  glBindBuffer(GL_PIXEL_PACK_BUFFER, library->pbo);
  glBindBuffer(GL_PIXEL_UNPACK_BUFFER, library->pbo);
```

```
  for (int level = 0, size = library_tex_size; size > 0; level += 1, size >>= 1)↙
      ↳ {
    glGetTexImage(GL_TEXTURE_2D, level, GL_RGB, GL_UNSIGNED_BYTE, 0);
    glTexSubImage3D(GL_TEXTURE_2D_ARRAY, level, 0, 0, layer, size, size, 1, ↙
        ↳ GL_RGB, GL_UNSIGNED_BYTE, 0);
  }
  glBindBuffer(GL_PIXEL_PACK_BUFFER, 0);
  glBindBuffer(GL_PIXEL_UNPACK_BUFFER, 0);
}

// find index to insert at
int library_index(struct library *library, float score) {
  if (library->count == library_tex_layers) {
    float minscore = score;
    int minindex = -1;
    for (int j = 0; j < library_tex_layers; ++j) {
      if (library->array[j].score <= minscore) {
        minscore = library->array[j].score;
        minindex = j;
      }
    }
    return minindex;
  } else {
    return library->count++;
  }
}

// pick a random point weighted by score
int library_pick(struct library *library, float *ru, float *rv, float *f, float ↙
    ↳ *k, float randomness) {
  double p = randomness * library->score * (rand() / (double) RAND_MAX);
  double s = 0.0;
  for (int i = 0; i < library->count; ++i) {
    s += library->array[i].score;
    if (p <= s) {
      *ru = library->array[i].v[0];
      *rv = library->array[i].v[1];
      *f  = library->array[i].v[2];
      *k  = library->array[i].v[3];
      return 0;
    }
  }
  return 1;
}

struct library *library_init(struct library *library, GLuint fbo) {
  if (!library) { return 0; }
  if (! borderwindow_init(&library->borderwindow)) { return 0; }
  if (! borderwindow_pick_init(&library->borderwindow_pick)) { return 0; }
  if (! worldsphere_init(&library->worldsphere)) { return 0; }
  if (! blur_init(&library->blur)) { return 0; }
  //if (! bloom_init(&library->bloom)) { return 0; }
  library->count = 0;
  library->frame = 0;
  camera_init(&library->camera);
  library->width = 1;
  library->height = 1;
```

```
  library->mousex = -1;
  library->mousey = -1;
  library->picked = -1;
  library->hover = -1;
  library->snap = 0;
  library->session = getenv("RDEX_SESSION");
  if (! library->session) { library->session = "."; }
  background_init(&library->background, library->session); //FIXME -- curl global init must be before any threads are created
  { // allocate texture array
    glGenTextures(1, &library->texture_array);
    glBindTexture(GL_TEXTURE_2D_ARRAY, library->texture_array);
    glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_MIN_FILTER, GL_LINEAR_MIPMAP_LINEAR);
    glTexParameteri(GL_TEXTURE_2D_ARRAY, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
    size_t bytes = library_tex_layers * library_tex_size * library_tex_size * 3;
    char *white = malloc(bytes);
    memset(white, 255, bytes);
    glTexImage3D(
      GL_TEXTURE_2D_ARRAY, 0, GL_RGB,
      library_tex_size, library_tex_size, library_tex_layers, 0,
      GL_RGB, GL_UNSIGNED_BYTE, white
    );
    glGenerateMipmap(GL_TEXTURE_2D_ARRAY);
    // allocate pixel buffer
    glGenBuffers(1, &library->pbo);
    glBindBuffer(GL_PIXEL_PACK_BUFFER, library->pbo);
    glBufferData(GL_PIXEL_PACK_BUFFER, library_tex_size * library_tex_size * 4, 0, GL_DYNAMIC_COPY);
    glBindBuffer(GL_PIXEL_PACK_BUFFER, 0);
    // allocate texture
    glEnable(GL_TEXTURE_2D);
    glGenTextures(1, &library->texture);
    glBindTexture(GL_TEXTURE_2D, library->texture);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR_MIPMAP_LINEAR);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
    glTexImage2D(
      GL_TEXTURE_2D, 0, GL_RGB,
      library_tex_size, library_tex_size, 0,
      GL_RGB, GL_UNSIGNED_BYTE, white
    );
    glGenerateMipmap(GL_TEXTURE_2D);
    free(white);
  }
  library->state = library_state_idle;
  library->phase = 0;
  library->loaded = 0;
  return library;
}

void library_insert(
  struct library *library,
  GLfloat ru, GLfloat rv, GLfloat f, GLfloat k, int index, GLfloat score
) {
  assert(0 <= index && index < library->count);
  // remove old element's stats
```

```
130     library->score -= library->array[index].score;
        library->score2 -= library->array[index].score * library->array[index].score;
        library->scorev[0] -= library->array[index].score * library->array[index].v↙
            ↳ [0];
        library->scorev[1] -= library->array[index].score * library->array[index].v↙
            ↳ [1];
        library->scorev[2] -= library->array[index].score * library->array[index].v↙
            ↳ [2];
135     library->scorev[3] -= library->array[index].score * library->array[index].v↙
            ↳ [3];
        library->scorev2[0] -= library->array[index].score * library->array[index].v↙
            ↳ [0] * library->array[index].v[0];
        library->scorev2[1] -= library->array[index].score * library->array[index].v↙
            ↳ [1] * library->array[index].v[1];
        library->scorev2[2] -= library->array[index].score * library->array[index].v↙
            ↳ [2] * library->array[index].v[2];
        library->scorev2[3] -= library->array[index].score * library->array[index].v↙
            ↳ [3] * library->array[index].v[3];
140     // fill element
        library->array[index].score = score;
        library->array[index].v[0] = ru;
        library->array[index].v[1] = rv;
        library->array[index].v[2] = f;
145     library->array[index].v[3] = k;
        library->array[index].spin[0] = 0;
        library->array[index].spin[1] = 0;
        library->array[index].dspin[0] = (rand() / (double) RAND_MAX - 0.5) / 32.0;
        library->array[index].dspin[1] = (rand() / (double) RAND_MAX - 0.5) / 32.0;
150     // add new element's stats
        library->score += library->array[index].score;
        library->score2 += library->array[index].score * library->array[index].score;
        library->scorev[0] += library->array[index].score * library->array[index].v↙
            ↳ [0];
        library->scorev[1] += library->array[index].score * library->array[index].v↙
            ↳ [1];
155     library->scorev[2] += library->array[index].score * library->array[index].v↙
            ↳ [2];
        library->scorev[3] += library->array[index].score * library->array[index].v↙
            ↳ [3];
        library->scorev2[0] += library->array[index].score * library->array[index].v↙
            ↳ [0] * library->array[index].v[0];
        library->scorev2[1] += library->array[index].score * library->array[index].v↙
            ↳ [1] * library->array[index].v[1];
        library->scorev2[2] += library->array[index].score * library->array[index].v↙
            ↳ [2] * library->array[index].v[2];
160     library->scorev2[3] += library->array[index].score * library->array[index].v↙
            ↳ [3] * library->array[index].v[3];
        // compute stats
        library->stddev[0] = sqrt((library->scorev2[0] * library->score - library->↙
            ↳ scorev[0] * library->scorev[0]) / (library->score * library->score - ↙
            ↳ library->score2));
        library->stddev[1] = sqrt((library->scorev2[1] * library->score - library->↙
            ↳ scorev[1] * library->scorev[1]) / (library->score * library->score - ↙
            ↳ library->score2));
        library->stddev[2] = sqrt((library->scorev2[2] * library->score - library->↙
            ↳ scorev[2] * library->scorev[2]) / (library->score * library->score - ↙
            ↳ library->score2));
```

```
165     library->stddev[3] = sqrt((library->scorev2[3] * library->score - library->↙
          ↳ scorev[3] * library->scorev[3]) / (library->score * library->score - ↙
          ↳ library->score2));
    }

    void library_addimage(struct library *library, GLuint fbo, GLuint t, int index) ↙
        ↳ {
      glEnable(GL_TEXTURE_2D);
170   glDisable(GL_DEPTH_TEST);
      glMatrixMode(GL_PROJECTION);
      glLoadIdentity();
      glViewport(0, 0, library_tex_size, library_tex_size);
      gluOrtho2D(0, 1, 0, 1);
175   glMatrixMode(GL_MODELVIEW);
      glLoadIdentity();
      glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
      // combine
      glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↙
          ↳ GL_TEXTURE_2D, library->texture, 0);
180   // packed texture
      glBindTexture(GL_TEXTURE_2D, t);
      glBegin(GL_QUADS); {
        glColor4f(1,1,1,1);
        glTexCoord2f(0, 0); glVertex2f(0, 0);
185     glTexCoord2f(1, 0); glVertex2f(1, 0);
        glTexCoord2f(1, 1); glVertex2f(1, 1);
        glTexCoord2f(0, 1); glVertex2f(0, 1);
      } glEnd();
      glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
190   glBindTexture(GL_TEXTURE_2D, library->texture);
      glGenerateMipmap(GL_TEXTURE_2D);
      library_copy_texture_to_array(library, index);
      glBindTexture(GL_TEXTURE_2D, 0);
    }
195
    int library_load(struct library *library, GLuint fbo) {
      glEnable(GL_TEXTURE_2D);
      /* temporary texture for loading */
      GLuint t;
200   glGenTextures(1, &t);
      glBindTexture(GL_TEXTURE_2D, t);
    //  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
    //  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
205   glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
      wordexp_t p;
      const char *pattern2 = "/ru_*__rv_*__f_*__k_*__s_*.ppm";
      int patternlen = strlen(library->session) + strlen(pattern2) + 1;
      char *pattern = malloc(patternlen);
210   snprintf(pattern, patternlen, "%s%s", library->session, pattern2);
      if (0 == wordexp(pattern, &p, WRDE_NOCMD | WRDE_SHOWERR | WRDE_UNDEF)) {
        char sru[9]; char srv[9]; char sf[9]; char sk[9]; char ss[9];
        for (int i = 0; i < p.we_wordc; ++i) {
          int l = strlen(p.we_wordv[i]);
215       const char *pattern3 = "ru_%8c__rv_%8c__f_%8c__k_%8c__s_%8c.ppm";
          const int expectLen = 3 + 8 + 5 + 8 + 4 + 8 + 4 + 8 + 4 + 8 + 4;
          if (
```

```
        l >= expectLen &&
        5 == sscanf(p.we_wordv[i] + l - expectLen, pattern3, sru, srv, sf, sk, ↙
            ↳ ss)
      ) {
        sru[8] = '\0'; srv[8] = '\0'; sf[8] = '\0'; sk[8] = '\0'; ss[8] = '\0';
        double ru, rv, f, k, s;
        int bsize = rdex_tex_size * rdex_tex_size * 3;
        char buffer[rdex_tex_size * rdex_tex_size * 3];
        if (1 != sscanf(sru, "%lg", &ru)) { break; }
        if (1 != sscanf(srv, "%lg", &rv)) { break; }
        if (1 != sscanf(sf,  "%lg", &f))  { break; }
        if (1 != sscanf(sk,  "%lg", &k))  { break; }
        if (1 != sscanf(ss,  "%lg", &s))  { break; }
        FILE *image = fopen(p.we_wordv[i], "rb");
        if (!image) { break; }
        fseek(image, -bsize, SEEK_END);
        if (fread(buffer, bsize, 1, image) != 1) {
          fprintf(stderr, "warning: failed to read image?\n");
        }
        fclose(image);
        glBindTexture(GL_TEXTURE_2D, t);
        glTexImage2D(
          GL_TEXTURE_2D, 0, GL_RGB,
          rdex_tex_size, rdex_tex_size, 0,
          GL_RGB, GL_UNSIGNED_BYTE, buffer
        );
        int index = library_index(library, s);
        if (index >= 0) {
          library_addimage(library, fbo, t, index);
          library_insert(library, ru, rv, f, k, index, s);
        }
      }
    }
    wordfree(&p);
  }
  free(pattern);
  glDeleteTextures(1, &t);
  glDisable(GL_TEXTURE_2D);
  return 1;
}

void library_display_save(
  struct library *library, GLuint fbo, GLuint texture, GLuint rawtexture,
  double ru, double rv, double f, double k, double score, const char *behaviour
) {
  library->target.v[0] = ru;
  library->target.v[1] = rv;
  library->target.v[2] = f;
  library->target.v[3] = k;
  // capture to library
  if (! library->snap) { return; }
  library->snap = 0;
  int index = library_index(library, score);
  if (index < 0) {
    return;
  }
  // downscale part of the original texture into the new texture
```

```
  glEnable(GL_TEXTURE_2D);
  library_addimage(library, fbo, texture, index);
/*
  // copy thumbnail texture to main memory as 1-byte data
  char *thumb_ppm = malloc(library_tex_size * library_tex_size * 3 + 1024);
  int thumb_ppm_bytes;
  thumb_ppm_bytes = snprintf(thumb_ppm, 1000, "P6\n%d %d 255\n", library_tex_size, library_tex_size);
  glReadPixels((index % library_pack) * library_tex_size, (index / library_pack) * library_tex_size, library_tex_size, library_tex_size, GL_RGB, GL_UNSIGNED_BYTE, thumb_ppm + thumb_ppm_bytes);
  thumb_ppm_bytes += library_tex_size * library_tex_size * 3;
*/
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
  // copy original texture to main memory as 1-byte data
  char *full_ppm = malloc(rdex_tex_size * rdex_tex_size * 3 + 1024);
  int full_ppm_bytes;
  full_ppm_bytes = snprintf(full_ppm, 1000, "P6\n%d %d 255\n", rdex_tex_size, rdex_tex_size);
  glBindTexture(GL_TEXTURE_2D, texture);
  glGetTexImage(GL_TEXTURE_2D, 0, GL_RGB, GL_UNSIGNED_BYTE, full_ppm + full_ppm_bytes);
  full_ppm_bytes += rdex_tex_size * rdex_tex_size * 3;
  // copy original raw texture to main memory as float data
  struct image *raw_image = image_alloc(rdex_tex_size, rdex_tex_size, 3);
  image_copytexture(raw_image, rawtexture);
  // copy original texture to main memory as float data
  struct image *full_image = image_alloc(rdex_tex_size, rdex_tex_size, 3);
  image_copytexture(full_image, texture);
  // pass all these images to the background thread, which will free them
  background_enqueue(&library->background, ru, rv, f, k, score, behaviour,
    /*thumb_ppm, thumb_ppm_bytes,*/ full_ppm, full_ppm_bytes, raw_image, full_image);
  // store in the library
  library_insert(library, ru, rv, f, k, index, score);
  glDisable(GL_TEXTURE_2D);
}

void library_reshape(struct library *library, int w, int h) {
  library->width = w;
  library->height = h;
//  bloom_reshape(&library->bloom, 1024, 1024); // FIXME hardcoded
}

void library_display(struct library *library, GLuint fbo, GLuint texture) {
  switch (library->state) {
    case library_state_intro:
      if (! library->loaded) {
        library_load(library, fbo);
        library->loaded = 1;
      } else {
        library->state = library_state_active;
      }
      // fall-through
    case library_state_active: {
      glEnable(GL_TEXTURE_2D);
      glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
```

```
325     /*
          glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
          glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, ↙
              ↳ GL_TEXTURE_2D, library->balltex, 0);
        */
          glViewport(0, 0, library->width, library->height);
330
          // update camera
          for (int i = 0; i < 4; ++i) {
            library->camera.scale.v[i] = library->stddev[i] > 0 ? 2.0 / library->↙
                ↳ stddev[i] : 1.0;
          }
335       for (int i = 0; i < 10; ++i) camera_update(&library->camera, &library->↙
              ↳ target);
          for (int i = 0; i < 4; ++i) {
            library->borderwindow.value.origin[i] = library->camera.C.v[i];
            library->borderwindow_pick.value.origin[i] = library->camera.C.v[i];
          }
340       for (int i = 0; i < 16; ++i) {
            library->borderwindow.value.rotate[i] = library->camera.M.m[i];
            library->borderwindow_pick.value.rotate[i] = library->camera.M.m[i];
          }
          for (int i = 0; i < 4; ++i) {
345         library->borderwindow.value.scale[i] = library->camera.scale.v[i];
            library->borderwindow_pick.value.scale[i] = library->camera.scale.v[i];
          }

          glClearColor(0,0,0,0);
350       glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);

        //  int width, height;
          glEnable(GL_TEXTURE_2D);
          glBindTexture(GL_TEXTURE_2D, texture);
355       glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
          glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
          glMatrixMode(GL_PROJECTION);
          glLoadIdentity();
          gluOrtho2D(0, 1, 0, 1);
360       glMatrixMode(GL_MODELVIEW);
          glLoadIdentity();
        //  glViewport(0, 0, library->width, library->height);
        //  glGetTexLevelParameteriv(
        //    GL_TEXTURE_2D, 0, GL_TEXTURE_WIDTH, &width
365     //  );
        //  glGetTexLevelParameteriv(
        //    GL_TEXTURE_2D, 0, GL_TEXTURE_HEIGHT, &height
        //  );
          library->worldsphere.value.size[0] = rdex_tex_size; //1024; //width;
370       library->worldsphere.value.size[1] = rdex_tex_size; //height;
          worldsphere_use(&library->worldsphere);
          glBegin(GL_QUADS); {
            float x = 3.0;
            float y = 3.0 * library->height / library->width;
375         glColor4f(1,1,1,1);
            glTexCoord4f(0.5 - x, 0.5 - y,  x, -y); glVertex2f(0, 0);
            glTexCoord4f(0.5 + x, 0.5 - y, -x, -y); glVertex2f(1, 0);
            glTexCoord4f(0.5 + x, 0.5 + y, -x,  y); glVertex2f(1, 1);
```

```
      glTexCoord4f(0.5 - x, 0.5 + y,   x,   y); glVertex2f(0, 1);
380   } glEnd();
      worldsphere_use(0);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);

385   // draw balls
      glEnable(GL_DEPTH_TEST);
      glMatrixMode(GL_PROJECTION);
      glLoadIdentity();
      float v = library->width / (float) library->height;
390   glFrustum(-v, v, -1, 1, 4, 12);
      glMatrixMode(GL_MODELVIEW);
      glLoadIdentity();
      glTranslatef(0, 0, -8);
      glScalef(2, 2, 2);
395   borderwindow_use(&library->borderwindow);
      float a = library->height / (float) library->width;
      for (int i = 0; i < library->count; ++i) {
        library->array[i].spin[0] += library->array[i].dspin[0];
        library->array[i].spin[0] -= floor(library->array[i].spin[0]);
400     library->array[i].spin[1] += library->array[i].dspin[1];
        library->array[i].spin[1] -= floor(library->array[i].spin[1]);
        GLfloat z  = sqrt(library->array[i].score) + 1.0/256.0;
        // note: y texcoord flipped for correct display from loaded image files
        int dx[4] = { 0, 1, 1, 0 };
405     int dy[4] = { 1, 1, 0, 0 };
        for (int j = 0; j < 4; ++j) {
          for (int k = 0; k < 4; ++k) {
            library->varray[i][j].vertex[k] = library->array[i].v[k];
          }
410       library->varray[i][j].texcoord[0] = i;
          library->varray[i][j].texcoord[1] = 0;
          library->varray[i][j].texcoord[2] = dx[j];
          library->varray[i][j].texcoord[3] = dy[j];
          library->varray[i][j].delta[0] = (dx[j] * 2 - 1) * z * a;
415       library->varray[i][j].delta[1] = (1 - 2 * dy[j]) * z;
          library->varray[i][j].spin[0] = library->array[i].spin[0];
          library->varray[i][j].spin[1] = library->array[i].spin[1];
        }
      }
420   glEnableClientState(GL_VERTEX_ARRAY);
      glEnableClientState(GL_TEXTURE_COORD_ARRAY);
      glEnableVertexAttribArray(library->borderwindow.attr.delta);
      glEnableVertexAttribArray(library->borderwindow.attr.spin);
      glVertexPointer  (4, GL_FLOAT, sizeof(struct libvert), &library->varray↙
          ↳ [0][0].vertex[0]);
425   glTexCoordPointer(4, GL_FLOAT, sizeof(struct libvert), &library->varray↙
          ↳ [0][0].texcoord[0]);
      glVertexAttribPointer(library->borderwindow.attr.delta, 2, GL_FLOAT, ↙
          ↳ GL_FALSE, sizeof(struct libvert), &library->varray[0][0].delta[0]);
      glVertexAttribPointer(library->borderwindow.attr.spin,  2, GL_FLOAT, ↙
          ↳ GL_FALSE, sizeof(struct libvert), &library->varray[0][0].spin[0]);
      glDrawArrays(GL_QUADS, 0, library->count * 4);
      glDisableClientState(GL_VERTEX_ARRAY);
430   glDisableClientState(GL_TEXTURE_COORD_ARRAY);
      glDisableVertexAttribArray(library->borderwindow.attr.delta);
```

```
        glDisableVertexAttribArray(library->borderwindow.attr.spin);

        // reset texture mode for accurate image save
435     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);
      //  glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
        borderwindow_use(0);
440     glDisable(GL_DEPTH_TEST);

        // apply bloom filter (modifies texture in place)
       // bloom_display(&library->bloom, fbo, library->balltex);
      /*
445     // draw balls
        glViewport(0, 0, 1024, 576);
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
        gluOrtho2D(0, 1, 0, 1);
450     glMatrixMode(GL_MODELVIEW);
        glLoadIdentity();
        glEnable(GL_TEXTURE_2D);
        glBindTexture(GL_TEXTURE_2D, library->balltex);
        glBegin(GL_QUADS); {
455       float x = 0.5;
          float y = 0.5 * 576.0/1024.0; // FIXME hardcoded
          glColor4f(1,1,1,1);
          glTexCoord2f(0.5 - x, 0.5 - y); glVertex2f(0, 0);
          glTexCoord2f(0.5 + x, 0.5 - y); glVertex2f(1, 0);
460       glTexCoord2f(0.5 + x, 0.5 + y); glVertex2f(1, 1);
          glTexCoord2f(0.5 - x, 0.5 + y); glVertex2f(0, 1);
        } glEnd();
      */
        glDisable(GL_TEXTURE_2D);
465

#if 0
        /* draw cursor */
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
470     gluOrtho2D(0, library->width, 0, library->height);
        glMatrixMode(GL_MODELVIEW);
        glLoadIdentity();
        glBegin(GL_LINES); {
          glColor4f(0,1,0,1);
475       glVertex2f(library->mousex, 0);
          glVertex2f(library->mousex, library->height);
          glVertex2f(0, library->mousey);
          glVertex2f(library->width, library->mousey);
        } glEnd();
480 #endif

        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
        library->frame += 1;
        break;
485   }

#if 0
    case library_state_intro: {
```

```
        if (! library->loaded) {
          library_load(library, fbo);
          library->loaded = 1;
        }
        glEnable(GL_TEXTURE_2D);
        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
        glViewport(0, 0, library->width, library->height);
        glClearColor(0,0,1,1);
        glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
        glEnable(GL_TEXTURE_2D);
        glBindTexture(GL_TEXTURE_2D, texture);
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
        gluOrtho2D(0, 1, 0, 1);
        glMatrixMode(GL_MODELVIEW);
        glLoadIdentity();
        library->worldsphere.value.size[0] = rdex_tex_size;
        library->worldsphere.value.size[1] = rdex_tex_size;
        worldsphere_use(&library->worldsphere);
        glBegin(GL_QUADS); {
          float x0 = 3.0;
          float y0 = x0 * library->height / library->width;
          float x1 = 3.0 / (library->phase * library->phase + 0.001);
          float y1 = x1 * library->height / library->width;
          glColor4f(1,1,1,1);
          glTexCoord4f(0.5 - x0, 0.5 - y0,  x1, -y1); glVertex2f(0, 0);
          glTexCoord4f(0.5 + x0, 0.5 - y0, -x1, -y1); glVertex2f(1, 0);
          glTexCoord4f(0.5 + x0, 0.5 + y0, -x1,  y1); glVertex2f(1, 1);
          glTexCoord4f(0.5 - x0, 0.5 + y0,  x1,  y1); glVertex2f(0, 1);
        } glEnd();
        worldsphere_use(0);
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
        glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
        library->phase += 0.04 / 25.0;
        if (! (library->phase < 1.0)) {
          library->state = library_state_active;
          library->phase = 0;
        }
        glBindTexture(GL_TEXTURE_2D, 0);
        glDisable(GL_TEXTURE_2D);
        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
        library->frame += 1;
        break;
      }
#endif
      case library_state_outro: {
        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
        glViewport(0, 0, library->width, library->height);
        glClearColor(0,0,1,1);
        glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
        break;
      }
      case library_state_idle:
      case library_state_done: {
```

```
        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
        glViewport(0, 0, library->width, library->height);
        glClearColor(0,0,0,1);
        glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
        glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
        break;
      }
    }
  }

void library_pmotion(struct library *library, int x, int y) {
  library->mousex = x;
  library->mousey = library->height - y - 1;
}

void library_amotion(struct library *library, int x, int y) {
  library->mousex = x;
  library->mousey = library->height - y - 1;
}

void library_mouse(struct library *library, int button, int state, int x, int y)
    {
  if (state == GLUT_DOWN) {
    library->picked = library->hover;
  }
}

void library_idle(struct library *library) {
  worldsphere_idle(&library->worldsphere);
}

// EOF
```

63 src/library.h

```
/* ==========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010,2019  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------
Library Module
========================================================================== */

#ifndef LIBRARY_H
#define LIBRARY_H 1

#include <GL/glew.h>
#include "borderwindow.h"
#include "worldsphere.h"
#include "background.h"
#include "matrix.h"
#include "camera.h"
//#include "bloom.h"
#include "blur.h"

//==========================================================================
// library data structures
```

```
#define library_tex_size 256
#define library_tex_layers 512

struct libelem {
  GLfloat v[4];       // raw parameter coordinates
  float score;        // analysis result
  float spin[2];      // spinning orbs
  float dspin[2];
};

struct libvert {
  GLfloat vertex[4];
  GLfloat texcoord[4];
  GLfloat delta[2];
  GLfloat spin[2];
};

struct library {
  int loaded;
  int count;          // invariant: count <= library_tex_layers
  struct libelem array[library_tex_layers];
  double score, score2, scorev[4], scorev2[4];
  GLfloat stddev[4];
  GLuint texture, texture_array;
  GLuint pbo;
  int which;
  unsigned int frame;
  int width;
  int height;
  int mousex;
  int mousey;
  GLuint picktex;
  int hover;
  int picked;
  int snap;
  char *session;
  struct borderwindow borderwindow;
  struct borderwindow_pick borderwindow_pick;
  struct worldsphere worldsphere;
  struct background background;
  struct camera camera;
  struct vec4 target;
//  struct bloom bloom;
  struct blur blur;
  GLuint blurtex[1]; // FIXME need log2(rdex_tex_size / library_tex_size)-1
//  GLuint balltex;
  enum { library_state_idle,
         library_state_intro,
         library_state_active,
         library_state_outro,
         library_state_done } state;
  double phase;
  // draw arrays stuff
  struct libvert varray[library_tex_layers][4];
};

//============================================================
```

```
80  // prototypes

    struct library *library_init(struct library *library, GLuint fbo);
    int library_load(struct library *library, GLuint fbo);
    void library_display_save(
85    struct library *library, GLuint fbo, GLuint texture, GLuint rawtexture,
      double ru, double rv, double f, double k, double score, const char *behaviour
    );
    void library_reshape(struct library *library, int w, int h);
    void library_display(struct library *library, GLuint fbo, GLuint texture);
90  void library_pmotion(struct library *library, int x, int y);
    void library_amotion(struct library *library, int x, int y);
    void library_mouse(struct library *library, int button, int state, int x, int y)↙
        ↳ ;
    void library_idle(struct library *library);
    int library_pick(struct library *library, float *ru, float *rv, float *f, float ↙
        ↳ *k, float randomness);
95
    #endif
```

64 src/list.c

```
    /* ================================================================
    rdex -- reaction-diffusion explorer
    Copyright (C) 2009  Claude Heiland-Allen <claude@mathr.co.uk>
    ----------------------------------------------------------------
 5  doubly-linked list implementation
    ================================================================ */

    #include <assert.h>
    #include "list.h"
10
    void list_init(struct list *l) {
      assert(l);
      l->head = &(l->headNode);
      l->tail = &(l->tailNode);
15    l->head->pred = 0;
      l->head->next = l->tail;
      l->tail->pred = l->head;
      l->tail->next = 0;
    }
20
    int list_ishead(struct node *n) {
      assert(n);
      return !n->pred;
    }
25
    int list_istail(struct node *n) {
      assert(n);
      return !n->next;
    }
30
    int list_isempty(struct list *l) {
      assert(l && l->head && l->tail);
      return l->head->next == l->tail;
    }
35
```

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

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

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;
  beforethis->pred = n;
}

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

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


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

// EOF
```

65 src/list.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2009,2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
doubly-linked list implementation
================================================================ */
```

```
#ifndef LIST_H
#define LIST_H 1

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

struct list {
  struct node *head;
  struct node *tail;
  // private
  struct node headNode;
  struct node tailNode;
};

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);
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);

#endif
```

66 src/main.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010,2017,2019  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Main Program Entry Point
================================================================ */

#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <GL/glew.h>
#include <GL/glut.h>

#ifdef RDEX_ICON
#include <GL/glx.h>
#include <X11/StringDefs.h>
#include <X11/Intrinsic.h>
#include <X11/IntrinsicP.h>
#include <X11/Shell.h>
#ifdef VMS
#include <X11/shape.h>
#else
#include <X11/extensions/shape.h>
#endif
```

```
25  #include <X11/xpm.h>
    #endif

    #include "rdex.h"

30  #ifdef RDEX_ICON
    #include "rdex-logo-32x32.xpm"

    struct XpmIcon {
      Pixmap pixmap;
35    Pixmap mask;
      XpmAttributes attributes;
    };
    #endif

40  int main(int argc, char **argv) {
      /* initialize GLUT etc */
      fprintf(stderr, "rdex (GPL) 2008-2019 Claude Heiland-Allen <claude@mathr.co.uk↙
          ↳ >\n");
      srand(time(NULL));
      glutInitDisplayMode(GLUT_RGBA | GLUT_DOUBLE | GLUT_DEPTH);
45    glutInitWindowSize(788, 576);
      glutInit(&argc, argv);
      glutCreateWindow("rdex");
      glutFullScreen();
      glutSetCursor(GLUT_CURSOR_NONE);
50    glewInit();
    #ifdef RDEX_ICON
      /* set icon */
      Display *display = glXGetCurrentDisplay();
      if (display) {
55      GLXDrawable drawable = glXGetCurrentDrawable();
        if (drawable) {
          struct XpmIcon icon;
          if (0 == XpmCreatePixmapFromData(display, drawable, rdex_logo_32x32_xpm, &↙
              ↳ icon.pixmap, &icon.mask, NULL)) {
            XWMHints* hints = XAllocWMHints();
60          if (hints) {
              hints->flags = IconPixmapHint;
              hints->icon_pixmap = icon.pixmap;
              if (icon.mask) {
                hints->flags |= IconMaskHint;
65              hints->icon_mask = icon.mask;
              }
              XSetWMHints(display, drawable, hints);
              XFree(hints);
            }
70        }
        }
      }
    #endif
      /* activate callbacks and enter main loop */
75    if (rdex_init()) {
        glutDisplayFunc(rdex_display);
        glutReshapeFunc(rdex_reshape);
        glutTimerFunc(1, rdex_timer, 0);
    //    glutIdleFunc(rdex_idle);
```

```
80        glutPassiveMotionFunc(rdex_pmotion);
          glutMotionFunc(rdex_amotion);
          glutMouseFunc(rdex_mouse);
          glutKeyboardFunc(rdex_keynormal);
          glutSpecialFunc(rdex_keyspecial);
85        glutSetCursor(GLUT_CURSOR_NONE);
          glutMainLoop();
          return 0; // never reached
        } else {
          return 1;
90      }
    }

    // EOF
```

67 src/Makefile

```
    #=============================================================================
    # rdex -- reaction-diffusion explorer
    # Copyright (C) 2008,2009,2010,2011,2017,2019  Claude Heiland-Allen <↙
        ↪ claude@mathr.co.uk>
    #-----------------------------------------------------------------------------
 5  # Makefile
    #=============================================================================

    CC = gcc
    CFLAGS = -std=c99 -Wall -pedantic -O3 -pthread `curl-config --cflags` `pkg-↙
        ↪ config --cflags jack` -D"_POSIX_C_SOURCE=199309L"
10  LIBS = -lGL -lGLU -lglut -lGLEW `curl-config --libs` `pkg-config --libs jack` -↙
        ↪ lsndfile -lm
    OBJS = main.o rdex.o shader.o arithmeticmean.o audio.o background.o blur.o ↙
        ↪ borderwindow.o copysquare.o difference.o falsecolour.o histogram.o image.o↙
        ↪  library.o list.o numericerror.o pfifo.o reactiondiffusion.o screenshot.o ↙
        ↪ segment.o tamura.o util.o worldsphere.o matrix.o camera.o gblur.o bloom.o ↙
        ↪ expcolour.o sequence.o glyph-curve-less.o glyph-curve-more.o glyph-speed-↙
        ↪ less.o glyph-speed-more.o glyphs.o intro.o intro-image.o timeline.o font.o↙
        ↪  fonts.o text.o
    GENC = arithmeticmean.frag.c audio.frag.c blur.frag.c borderwindow.frag.c ↙
        ↪ borderwindow_pick.frag.c copysquare.frag.c difference.frag.c falsecolour.↙
        ↪ frag.c numericerror.frag.c reactiondiffusion.frag.c worldsphere.frag.c ↙
        ↪ projection.vert.c projection_pick.vert.c gblur.frag.c bloom.frag.c ↙
        ↪ expcolour.frag.c sequence.frag.c sequence.vert.c text.frag.c text.vert.c

    # optional feature: window icon
15  CFLAGS += -DRDEX_ICON
    LIBS += -lXpm -lX11
    # optional feature: debuggability
    #CFLAGS += -ggdb -pg
    CFLAGS += -march=native -mfpmath=sse -ffast-math
20
    all: rdex

    clean:
            -rm -f $(OBJS) $(GENC)
25
    # no suffix rules, they cause weird issues with the .frag.c files
    .SUFFIXES:
```

```
.PHONY: all clean

# link program
rdex: $(OBJS)
	$(CC) $(CFLAGS) -o rdex $(OBJS) $(LIBS)

# C source to object file
%.o: %.c
	$(CC) $(CFLAGS) -o $@ -c $<

# shader source to C source
%.frag.c: %.frag s2c.sh
	./s2c.sh $*_frag < $< > $@

%.vert.c: %.vert s2c.sh
	./s2c.sh $*_vert < $< > $@

# svg to rasterized RGBA object
%.o: %.svg svg2o.sh interleave31
	./svg2o.sh $*

# png to rasterized RGBA object
%.o: %.png png2o.sh interleave31
	./png2o.sh $*

interleave31: interleave31.c
	$(CC) $(CFLAGS) -s -o interleave31 interleave31.c

interleave31_1024: interleave31_1024.c
	$(CC) $(CFLAGS) -s -o interleave31_1024 interleave31_1024.c

# dependencies
arithmeticmean.o: arithmeticmean.c arithmeticmean.frag.c arithmeticmean.h shader.h util.h
audio.o: audio.c audio.h audio.frag.c shader.h
background.o: background.c background.h pfifo.h image.h histogram.h segment.h
bloom.o: bloom.c bloom.frag.c bloom.h gblur.h shader.h util.h
blur.o: blur.c blur.frag.c blur.h shader.h
borderwindow.o: borderwindow.c borderwindow.frag.c borderwindow_pick.frag.c borderwindow.h shader.h projection.vert.c projection_pick.vert.c
camera.o: camera.c camera.h matrix.h
copysquare.o: copysquare.c copysquare.frag.c copysquare.h shader.h util.h
difference.o: difference.c difference.frag.c difference.h shader.h arithmeticmean.h util.h
expcolour.o: expcolour.c expcolour.frag.c expcolour.h shader.h
falsecolour.o: falsecolour.c falsecolour.frag.c falsecolour.h shader.h util.h blur.h
fonts.o: fonts.c fonts.h
gblur.o: gblur.c gblur.frag.c gblur.h expcolour.h shader.h util.h
glyphs.o: glyphs.c glyphs.h
histogram.o: histogram.c histogram.h image.h
image.o: image.c image.h
intro.o: intro.c intro.h
library.o: library.c library.h background.h borderwindow.h image.h rdex.h shader.h tamura.h matrix.h
list.o: list.c list.h
main.o: main.c rdex.h
```

```
80  matrix.o: matrix.c matrix.h
    numericerror.o: numericerror.c numericerror.frag.c numericerror.h shader.h ↙
        ↳ arithmeticmean.h util.h
    pfifo.o: pfifo.c pfifo.h list.h
    rdex.o: rdex.c rdex.h arithmeticmean.h copysquare.h difference.h falsecolour.h ↙
        ↳ library.h numericerror.h reactiondiffusion.h screenshot.h sequence.h audio↙
        ↳ .h
    reactiondiffusion.o: reactiondiffusion.c reactiondiffusion.frag.c ↙
        ↳ reactiondiffusion.h shader.h util.h
85  screenshot.o: screenshot.c screenshot.h pfifo.h
    segment.o: segment.c segment.h image.h util.h
    sequence.o: sequence.c sequence.h library.h reactiondiffusion.h sequence.frag.c ↙
        ↳ sequence.vert.c glyphs.h
    shader.o: shader.c shader.h
    tamura.o: tamura.c tamura.h image.h
90  text.o: text.c text.h shader.h fonts.h text.frag.c text.vert.c
    timeline.o: timeline.c timeline.h
    util.o: util.c util.h
    worldsphere.o: worldsphere.c worldsphere.frag.c worldsphere.h shader.h

95  # EOF
```

68 src/matrix.c

```
    /* ================================================================
    rdex -- reaction-diffusion explorer
    Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
    ----------------------------------------------------------------
 5  Matrix computations
    ================================================================ */

    #include <math.h>
    #include <stdio.h>
10  #include "matrix.h"

    // vector copy

    void vcopy3(struct vec3 *m, struct vec3 *x) {
15    for (int i = 0; i < 3; ++i) {
        m->v[i] = x->v[i];
      }
    }

20  void vcopy4(struct vec4 *m, struct vec4 *x) {
      for (int i = 0; i < 4; ++i) {
        m->v[i] = x->v[i];
      }
    }
25
    void vcopy5(struct vec5 *m, struct vec5 *x) {
      for (int i = 0; i < 5; ++i) {
        m->v[i] = x->v[i];
      }
30  }

    // matrix copy
```

```
void mcopy3(struct mat3 *m, struct mat3 *x) {
  for (int i = 0; i < 9; ++i) {
    m->m[i] = x->m[i];
  }
}

void mcopy4(struct mat4 *m, struct mat4 *x) {
  for (int i = 0; i < 16; ++i) {
    m->m[i] = x->m[i];
  }
}

void mcopy5(struct mat5 *m, struct mat5 *x) {
  for (int i = 0; i < 25; ++i) {
    m->m[i] = x->m[i];
  }
}

// vector scalar multiplication

void vsmul3(struct vec3 *m, struct vec3 *x, float y) {
  for (int i = 0; i < 3; ++i) {
    m->v[i] = x->v[i] * y;
  }
}

void vsmul4(struct vec4 *m, struct vec4 *x, float y) {
  for (int i = 0; i < 4; ++i) {
    m->v[i] = x->v[i] * y;
  }
}

void vsmul5(struct vec5 *m, struct vec5 *x, float y) {
  for (int i = 0; i < 5; ++i) {
    m->v[i] = x->v[i] * y;
  }
}

// vector scalar division

void vsdiv3(struct vec3 *m, struct vec3 *x, float y) {
  for (int i = 0; i < 3; ++i) {
    m->v[i] = x->v[i] / y;
  }
}

void vsdiv4(struct vec4 *m, struct vec4 *x, float y) {
  for (int i = 0; i < 4; ++i) {
    m->v[i] = x->v[i] / y;
  }
}

void vsdiv5(struct vec5 *m, struct vec5 *x, float y) {
  for (int i = 0; i < 5; ++i) {
    m->v[i] = x->v[i] / y;
  }
}
```

```
// vector vector addition

void vvadd3(struct vec3 *m, struct vec3 *x, struct vec3 *y) {
  for (int i = 0; i < 3; ++i) {
    m->v[i] = x->v[i] + y->v[i];
  }
}

void vvadd4(struct vec4 *m, struct vec4 *x, struct vec4 *y) {
  for (int i = 0; i < 4; ++i) {
    m->v[i] = x->v[i] + y->v[i];
  }
}

void vvadd5(struct vec5 *m, struct vec5 *x, struct vec5 *y) {
  for (int i = 0; i < 5; ++i) {
    m->v[i] = x->v[i] + y->v[i];
  }
}

// vector vector subtraction

void vvsub3(struct vec3 *m, struct vec3 *x, struct vec3 *y) {
  for (int i = 0; i < 3; ++i) {
    m->v[i] = x->v[i] - y->v[i];
  }
}

void vvsub4(struct vec4 *m, struct vec4 *x, struct vec4 *y) {
  for (int i = 0; i < 4; ++i) {
    m->v[i] = x->v[i] - y->v[i];
  }
}

void vvsub5(struct vec5 *m, struct vec5 *x, struct vec5 *y) {
  for (int i = 0; i < 5; ++i) {
    m->v[i] = x->v[i] - y->v[i];
  }
}

// vector vector multiplication (componentwise)

void vvmul4(struct vec4 *m, struct vec4 *x, struct vec4 *y) {
  for (int i = 0; i < 4; ++i) {
    m->v[i] = x->v[i] * y->v[i];
  }
}

// vector vector division (componentwise)

void vvdiv4(struct vec4 *m, struct vec4 *x, struct vec4 *y) {
  for (int i = 0; i < 4; ++i) {
    m->v[i] = x->v[i] / y->v[i];
  }
}
```

```
// matrix vector multiplication

void mvmul3(struct vec3 *v, struct mat3 *x, struct vec3 *y) {
  int k = 0;
  for (int i = 0; i < 3; ++i) {
    v->v[i] = 0;
    for (int j = 0; j < 3; ++j) {
      v->v[i] += x->m[k++] * y->v[j];
    }
  }
}

void mvmul4(struct vec4 *v, struct mat4 *x, struct vec4 *y) {
  int k = 0;
  for (int i = 0; i < 4; ++i) {
    v->v[i] = 0;
    for (int j = 0; j < 4; ++j) {
      v->v[i] += x->m[k++] * y->v[j];
    }
  }
}

void mvmul5(struct vec5 *v, struct mat5 *x, struct vec5 *y) {
  int k = 0;
  for (int i = 0; i < 5; ++i) {
    v->v[i] = 0;
    for (int j = 0; j < 5; ++j) {
      v->v[i] += x->m[k++] * y->v[j];
    }
  }
}

// matrix matrix multiplication

void mmmul3(struct mat3 *m, struct mat3 *x, struct mat3 *y) {
  const int N = 3;
  int kk = 0;
  for (int i = 0; i < N; ++i) {
    for (int j = 0; j < N; ++j) {
      m->m[kk] = 0;
      for (int k = 0; k < N; ++k) {
        m->m[kk] += x->m[k * N + j] * y->m[i * N + k];
      }
      kk++;
    }
  }
}

void mmmul4(struct mat4 *m, struct mat4 *x, struct mat4 *y) {
  const int N = 4;
  int kk = 0;
  for (int i = 0; i < N; ++i) {
    for (int j = 0; j < N; ++j) {
      m->m[kk] = 0;
      for (int k = 0; k < N; ++k) {
        m->m[kk] += x->m[k * N + j] * y->m[i * N + k];
```

```
205         }
            kk++;
          }
        }
      }
210
      void mmmul5(struct mat5 *m, struct mat5 *x, struct mat5 *y) {
        const int N = 5;
        int kk = 0;
        for (int i = 0; i < N; ++i) {
215       for (int j = 0; j < N; ++j) {
            m->m[kk] = 0;
            for (int k = 0; k < N; ++k) {
              m->m[kk] += x->m[k * N + j] * y->m[i * N + k];
            }
220         kk++;
          }
        }
      }

225   // homogeneous matrix construction

      void identity3(struct mat3 *m) {
        const int N = 3;
        int k = 0;
230     for (int i = 0; i < N; ++i) {
        for (int j = 0; j < N; ++j) {
          m->m[k++] = (i == j);
        } }
      }
235
      void identity4(struct mat4 *m) {
        const int N = 4;
        int k = 0;
        for (int i = 0; i < N; ++i) {
240     for (int j = 0; j < N; ++j) {
          m->m[k++] = (i == j);
        } }
      }

245   void identity5(struct mat5 *m) {
        const int N = 5;
        int k = 0;
        for (int i = 0; i < N; ++i) {
        for (int j = 0; j < N; ++j) {
250       m->m[k++] = (i == j);
        } }
      }

      void homogen4(struct mat4 *m, struct mat3 *x) {
255     m->m[ 0] = x->m[0]; m->m[ 1] = x->m[1]; m->m[ 2] = x->m[2]; m->m[ 3] = 0;
        m->m[ 4] = x->m[3]; m->m[ 5] = x->m[4]; m->m[ 6] = x->m[5]; m->m[ 7] = 0;
        m->m[ 8] = x->m[6]; m->m[ 9] = x->m[7]; m->m[10] = x->m[8]; m->m[11] = 0;
        m->m[12] = 0;       m->m[13] = 0;       m->m[14] = 0;       m->m[15] = 1;
      }
260
      void homogen5(struct mat5 *m, struct mat4 *x) {
```

```
  m->m[ 0] = x->m[ 0]; m->m[ 1] = x->m[ 1]; m->m[ 2] = x->m[ 2]; m->m[ 3] = x->m[ 3]; m->m[ 4] = 0;
  m->m[ 5] = x->m[ 4]; m->m[ 6] = x->m[ 5]; m->m[ 7] = x->m[ 6]; m->m[ 8] = x->m[ 7]; m->m[ 9] = 0;
  m->m[10] = x->m[ 8]; m->m[11] = x->m[ 9]; m->m[12] = x->m[10]; m->m[13] = x->m[11]; m->m[14] = 0;
  m->m[15] = x->m[12]; m->m[16] = x->m[13]; m->m[17] = x->m[14]; m->m[18] = x->m[15]; m->m[19] = 0;
  m->m[20] = 0;        m->m[21] = 0;        m->m[22] = 0;        m->m[23] = 0;        m->m[24] = 1;
}

void translate4(struct mat4 *m, struct vec3 *v) {
  const int N = 4;
  identity4(m);
  int k = N - 1;
  for (int i = 0; i < N - 1; ++i) {
    m->m[k] = v->v[i];
    k += N;
  }
}

void translate5(struct mat5 *m, struct vec4 *v) {
  const int N = 5;
  identity5(m);
  int k = N - 1;
  for (int i = 0; i < N - 1; ++i) {
    m->m[k] = v->v[i];
    k += N;
  }
}

// rolling ball

void rollingball4(struct mat4 *m, float R, struct vec3 *v) {
  float r = sqrt(v->v[0] * v->v[0] + v->v[1] * v->v[1] + v->v[2] * v->v[2]);
  float D = sqrt(R*R+r*r);
  float c = R / D;
  float s = r / D;
  float x, y, z;
  if (r > 0.00001) {
    x = v->v[0] / r;
    y = v->v[1] / r;
    z = v->v[2] / r;
  } else {
    x = 0;
    y = 0;
    z = 0;
  }
  float t[16] = {
    1-x*x*(1-c), -(1-c)*x*y,  -(1-c)*x*z,  s*x,
    -(1-c)*x*y,  1-y*y*(1-c), -(1-c)*y*z,  s*y,
    -(1-c)*x*z,  -(1-c)*y*z,  1-z*z*(1-c), s*z,
    -s*x,        -s*y,        -s*z,        c
  };
  for (int i = 0; i < 16; ++i) {
    m->m[i] = t[i];
```

```
  }
}

// helper functions

float vlength4(struct vec4 *x) {
  float v = 0;
  for (int i = 0; i < 4; ++i) {
    v += x->v[i] * x->v[i];
  }
  return sqrt(v);
}

float vdistance4(struct vec4 *x, struct vec4 *y) {
  struct vec4 d;
  vvsub4(&d, x, y);
  return vlength4(&d);
}

float vvdot4(struct vec4 *x, struct vec4 *y) {
  float v = 0;
  for (int i = 0; i < 4; ++i) {
    v += x->v[i] * y->v[i];
  }
  return v;
}

// debugging

void vprint4(struct vec4 *m) {
  fprintf(stderr, "%f %f %f %f\n", m->v[0], m->v[1], m->v[2], m->v[3]);
}

void mprint4(struct mat4 *m) {
  fprintf(
    stderr, "%f %f %f %f\n%f %f %f %f\n%f %f %f %f\n%f %f %f %f\n",
    m->m[ 0], m->m[ 1], m->m[ 2], m->m[ 3],
    m->m[ 4], m->m[ 5], m->m[ 6], m->m[ 7],
    m->m[ 8], m->m[ 9], m->m[10], m->m[11],
    m->m[12], m->m[13], m->m[14], m->m[15]
  );
}

// EOF
```

69 src/matrix.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Matrix computations
================================================================ */

#ifndef MATRIX_H
#define MATRIX_H 1

```

```
// data structures
struct vec3 { float v[3]; };
struct vec4 { float v[4]; };
struct vec5 { float v[5]; };
struct mat3 { float m[3*3]; };
struct mat4 { float m[4*4]; };
struct mat5 { float m[5*5]; };

// copying
void vcopy3(struct vec3 *m, struct vec3 *x);
void vcopy4(struct vec4 *m, struct vec4 *x);
void vcopy5(struct vec5 *m, struct vec5 *x);
void mcopy3(struct mat3 *m, struct mat3 *x);
void mcopy4(struct mat4 *m, struct mat4 *x);
void mcopy5(struct mat5 *m, struct mat5 *x);

// basic operations
void vsmul3(struct vec3 *m, struct vec3 *x, float y);
void vsmul4(struct vec4 *m, struct vec4 *x, float y);
void vsmul5(struct vec5 *m, struct vec5 *x, float y);
void vsdiv3(struct vec3 *m, struct vec3 *x, float y);
void vsdiv4(struct vec4 *m, struct vec4 *x, float y);
void vsdiv5(struct vec5 *m, struct vec5 *x, float y);

void vvadd3(struct vec3 *m, struct vec3 *x, struct vec3 *y);
void vvadd4(struct vec4 *m, struct vec4 *x, struct vec4 *y);
void vvadd5(struct vec5 *m, struct vec5 *x, struct vec5 *y);
void vvsub3(struct vec3 *m, struct vec3 *x, struct vec3 *y);
void vvsub4(struct vec4 *m, struct vec4 *x, struct vec4 *y);
void vvsub5(struct vec5 *m, struct vec5 *x, struct vec5 *y);

void vvmul4(struct vec4 *m, struct vec4 *x, struct vec4 *y);
void vvdiv4(struct vec4 *m, struct vec4 *x, struct vec4 *y);

void mvmul3(struct vec3 *v, struct mat3 *x, struct vec3 *y);
void mvmul4(struct vec4 *v, struct mat4 *x, struct vec4 *y);
void mvmul5(struct vec5 *v, struct mat5 *x, struct vec5 *y);

void mmmul3(struct mat3 *m, struct mat3 *x, struct mat3 *y);
void mmmul4(struct mat4 *m, struct mat4 *x, struct mat4 *y);
void mmmul5(struct mat5 *m, struct mat5 *x, struct mat5 *y);

// homogeneous matrix construction
void identity3(struct mat3 *m);
void identity4(struct mat4 *m);
void identity5(struct mat5 *m);
void homogen4(struct mat4 *m, struct mat3 *x);
void homogen5(struct mat5 *m, struct mat4 *x);
void translate4(struct mat4 *m, struct vec3 *v);
void translate5(struct mat5 *m, struct vec4 *v);
void rollingball4(struct mat4 *m, float R, struct vec3 *v);

// helper functions
float vlength4(struct vec4 *x);
float vdistance4(struct vec4 *x, struct vec4 *y);
float vvdot4(struct vec4 *x, struct vec4 *y);
```

```
// debugging
void vprint4(struct vec4 *m);
void mprint4(struct mat4 *m);

#endif
```

70 src/numericerror.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Numeric Error Shader
================================================================ */

#include "util.h"
#include "numericerror.h"
#include "numericerror.frag.c"

//==============================================================
// numeric error shader initialization
struct numericerror *numericerror_init(
  struct numericerror *numericerror
) {
  if (! numericerror) { return 0; }
  if (! shader_init(&numericerror->shader, 0, numericerror_frag)) {
    return 0;
  }
  shader_uniform(numericerror, texture);
  shader_uniform(numericerror, dx);
  shader_uniform(numericerror, dy);
  numericerror->value.texture = 0;
  numericerror->value.dx      = 0;
  numericerror->value.dy      = 0;
  if (! arithmeticmean_init(&numericerror->arithmeticmean)) {
    return 0;
  }
  glGenTextures(1, &numericerror->texture);
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, numericerror->texture);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  glDisable(GL_TEXTURE_2D);
  numericerror->width = 0;
  numericerror->height = 0;
  numericerror->calc = 0;
  numericerror->mean = 0;
  return numericerror;
}

//==============================================================
// numeric error shader reshape callback
void numericerror_reshape(
  struct numericerror *numericerror, int w, int h
) {
  numericerror->width  = roundtwo(w);
  numericerror->height = roundtwo(h);
```

```
50    numericerror->value.dx = 1.0 / numericerror->width;
      numericerror->value.dy = 1.0 / numericerror->height;
      glEnable(GL_TEXTURE_2D);
      glBindTexture(GL_TEXTURE_2D, numericerror->texture);
      glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA32F_ARB,
55      numericerror->width, numericerror->height, 0, GL_RGBA, GL_FLOAT, 0
      );
      glDisable(GL_TEXTURE_2D);
      arithmeticmean_reshape(&numericerror->arithmeticmean, w, h);
    }
60
    //=============================================================
    // numeric error shader display callback
    void numericerror_display(
      struct numericerror *numericerror, GLuint fbo, GLuint texture
65  ) {
      if (numericerror->calc) {
        glEnable(GL_TEXTURE_2D);
        glBindTexture(GL_TEXTURE_2D, texture);
        //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
70      glFramebufferTexture2DEXT(
          GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
          numericerror->texture, 0
        );
        glUseProgramObjectARB(numericerror->shader.program);
75      shader_updatei(numericerror, texture);
        shader_updatef(numericerror, dx);
        shader_updatef(numericerror, dy);
        glMatrixMode(GL_PROJECTION);
        glLoadIdentity();
80      gluOrtho2D(0, 1, 0, 1);
        glMatrixMode(GL_MODELVIEW);
        glLoadIdentity();
        glViewport(0, 0, numericerror->width, numericerror->height);
        glBegin(GL_QUADS); { glColor4f(1,1,1,1);
85        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();
90      glUseProgramObjectARB(0);
        //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
        glDisable(GL_TEXTURE_2D);
        arithmeticmean_display(
          &numericerror->arithmeticmean, fbo, numericerror->texture
95      );
        numericerror->mean = numericerror->arithmeticmean.result[0];
        numericerror->calc = 0;
      }
    }
100
    //=============================================================
    // numeric error shader idle callback
    void numericerror_idle(struct numericerror *numericerror) {
      arithmeticmean_idle(&numericerror->arithmeticmean);
105 }
```

```
// EOF
```

71 src/numericerror.frag

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
================================================================ */

uniform sampler2D texture; // U := r, V := g, other channels ignored
uniform float dx;          // horizontal distance between texels
uniform float dy;          // vertical distance between texels

void main(void) {
  vec2 p = gl_TexCoord[0].st;                          // coordinates
  vec2 gx = texture2D(texture, p + vec2(-dx,0.0)).rg  // x-wards edge
          + texture2D(texture, p + vec2( dx,0.0)).rg
          - texture2D(texture, p + vec2(0.0,0.0)).rg * 2.0;
  vec2 gy = texture2D(texture, p + vec2(0.0,-dy)).rg  // y-wards edge
          + texture2D(texture, p + vec2(0.0, dy)).rg
          - texture2D(texture, p + vec2(0.0,0.0)).rg * 2.0;
  vec2 xy = texture2D(texture, p + vec2(-dx,-dy)).rg  // xy-wards edge
          + texture2D(texture, p + vec2( dx, dy)).rg
          - texture2D(texture, p + vec2(0.0,0.0)).rg * 2.0;
  vec2 yx = texture2D(texture, p + vec2( dx, dy)).rg  // yx-wards edge
          + texture2D(texture, p + vec2(-dx,-dy)).rg
          - texture2D(texture, p + vec2(0.0,0.0)).rg * 2.0;
  float e = sqrt(dot(gx,gx)+dot(gy,gy)+dot(xy,xy)+dot(yx,yx));
  gl_FragColor = vec4(e, e, e, 1.0);                    // total edges
}
```

72 src/numericerror.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Numeric Error Shader
================================================================ */

#ifndef NUMERICERROR_H
#define NUMERICERROR_H 1

#include "arithmeticmean.h"

//================================================================
// numeric error shader data
struct numericerror { struct shader shader;
  struct { GLint texture; GLint dx; GLint dy; } uniform;
  struct { int   texture; float dx; float dy; } value;
  struct arithmeticmean arithmeticmean;
  GLuint texture;
  int width;
  int height;
  int calc;
  float mean;
```

```
};

//=============================================================
// prototypes
struct numericerror *numericerror_init(
  struct numericerror *numericerror
);
void numericerror_reshape(
  struct numericerror *numericerror, int w, int h
);
void numericerror_display(
  struct numericerror *numericerror, GLuint fbo, GLuint texture
);
void numericerror_idle(struct numericerror *numericerror);

#endif
```

73 src/pfifo.c

```
/* =============================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2009,2010  Claude Heiland-Allen <claude@mathr.co.uk>
-------------------------------------------------------------------
pthread-based fifo
============================================================= */

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

//#include <stdio.h>

//=============================================================
// prototypes
void *pfifo_consumerthread(void *);

//=============================================================
// create a new fifo with a consumer thread
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->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));
  pthread_cond_init(p->nonempty, 0);
  pthread_create(&(p->thread), 0, pfifo_consumerthread, p);
  return p;
}

//=============================================================
// append to the fifo, copying data
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;
  n->data = malloc(length);
  assert(n->data);
  memcpy(n->data, data, length);
  pthread_mutex_lock(p->mutex);
  list_inserttail(&(p->list), &(n->node));
  //int i = list_length(&(p->list));
  pthread_mutex_unlock(p->mutex);
  pthread_cond_signal(p->nonempty);
  //fprintf(stderr, "\ndebug: pfifo size %d\n", i);
}

//============================================================
// loop running consumer callback on each fifo item, freeing data
void *pfifo_consumerthread(void *fifo) {
  struct pfifo *p = fifo;
  while (1) {
    pthread_mutex_lock(p->mutex);
    while (list_isempty(&(p->list))) pthread_cond_wait(p->nonempty, p->mutex);
    struct pfifo_node *n = (struct pfifo_node *) list_removehead(&(p->list));
    pthread_mutex_unlock(p->mutex);
    p->consumer(p->consumerdata, n->length, n->data);
    free(n->data);
    free(n);
  }
  return 0;
}


// EOF
```

74 src/pfifo.h

```
/* ============================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2009  Claude Heiland-Allen <claude@mathr.co.uk>
------------------------------------------------------------
pthread-based fifo
============================================================ */

#ifndef PFIFO_H
#define PFIFO_H 1

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

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

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

struct pfifo {
  pfifo_consumer *consumer;
```

```
25    void *consumerdata;
      struct list list;
      pthread_t thread;
      pthread_mutex_t *mutex;
      pthread_cond_t *nonempty;
30  };

    struct pfifo *pfifo_create(pfifo_consumer *consumer, void *consumerdata);
    void pfifo_destroy(struct pfifo *fifo);
    void pfifo_enqueue(struct pfifo *fifo, size_t length, const void *data);
35
    #endif
```

75 src/png2o.sh

```
    #!/bin/bash
    PNGFILE="${1}.png"
    PPMFILE="${1}.ppm"
    PGMFILE="${1}.pgm"
 5  RGBFILE="${1}.rgb"
    AFILE="${1}.a"
    RGBAFILE="${1}.rgba"
    OFILE="${1}.o"
    PNGSIZE="$(identify -format "%w" "${PNGFILE}")"
10  pngtopnm        "${PNGFILE}" > "${PPMFILE}"
    pngtopnm -alpha "${PNGFILE}" > "${PGMFILE}"
    tail -c "$(( 3*${PNGSIZE}*${PNGSIZE} ))" "${PPMFILE}" > "${RGBFILE}"
    tail -c "$(( 1*${PNGSIZE}*${PNGSIZE} ))" "${PGMFILE}" > "${AFILE}"
    ./interleave31 "${RGBFILE}" "${AFILE}" "${PNGSIZE}" > "${RGBAFILE}"
15  #objcopy --input binary --output elf32-i386 --binary-architecture i386 "${↙
        ↘ RGBAFILE}" "${OFILE}"
    objcopy --input binary --output elf64-x86-64 --binary-architecture i386 "${↙
        ↘ RGBAFILE}" "${OFILE}"
    rm -f "${PPMFILE}" "${PGMFILE}" "${RGBFILE}" "${AFILE}" "${RGBAFILE}"
```

76 src/projection_pick.vert

```
    /* ================================================================
    rdex -- reaction-diffusion explorer
    Copyright (C) 2010,2011,2019  Claude Heiland-Allen <claude@mathr.co.uk>
    ----------------------------------------------------------------
 5  4D->3D projection shader for ball picking
    ================================================================ */

    // 4D perspective projection
    uniform vec4 origin;
10  uniform vec4 scale;
    uniform mat4 rotate;
    uniform vec4 translate;
    uniform vec4 near;
    uniform vec4 far;
15
    // billboarding
    attribute vec2 delta;

    varying float ignore;
```

```
20
    void main(void) {
      vec4 p0 = rotate * (0.5 * scale * (gl_Vertex - origin));
      vec4 p = p0 + translate;
      mat4 m = mat4(
25      2.0*near.w/(far.x - near.x), 0.0, 0.0, (far.x + near.x)/(far.x - near.x),
        0.0, 2.0*near.w/(far.y - near.y), 0.0, (far.y + near.y)/(far.y - near.y),
        0.0, 0.0, 2.0*near.w/(far.z - near.z), (far.z + near.z)/(far.z - near.z),
        0.0, 0.0, 0.0,                         (far.w + near.w)/(far.w - near.w)
      );
30    float k = 2.0 * near.w * far.w / (far.w - near.w);
      vec4 q = m * p;
      q.w -= k;
      q /= p.w;
      vec4 v = vec4(10000.0, 10000.0, 10000.0, 1.0); // way off-screen
35    float r2 = dot(p0,p0) * 0.5;
      float s = 0.0;
      if (r2 < 1.0) {
        s = sqrt(1.0 - r2);
        v = gl_ModelViewProjectionMatrix * q;
40      v.xy += delta * s;
        ignore = 0.0;
      } else {
        ignore = 1.0;
      }
45    gl_TexCoord[0] = gl_MultiTexCoord0;
      gl_Position = v;
    }
```

77 src/projection.vert

```
    /* ================================================================
    rdex -- reaction-diffusion explorer
    Copyright (C) 2010,2011,2019  Claude Heiland-Allen <claude@mathr.co.uk>
    ----------------------------------------------------------------------
 5  4D->3D projection shader
    ================================================================ */

    // 4D perspective projection
    uniform vec4 origin;
10  uniform vec4 scale;
    uniform mat4 rotate;
    uniform vec4 translate;
    uniform vec4 near;
    uniform vec4 far;
15
    // billboarding
    attribute vec2 delta;

    // spinning orbs
20  attribute vec2 spin;

    // ball picking
    attribute float pick;

25  varying vec2 spin2;
    varying float scale2;
```

```
varying float pick2;

varying float ignore;

void main(void) {
  vec4 p0 = rotate * (0.5 * scale * (gl_Vertex - origin));
  vec4 p = p0 + translate;
  mat4 m = mat4(
    2.0*near.w/(far.x - near.x), 0.0, 0.0, (far.x + near.x)/(far.x - near.x),
    0.0, 2.0*near.w/(far.y - near.y), 0.0, (far.y + near.y)/(far.y - near.y),
    0.0, 0.0, 2.0*near.w/(far.z - near.z), (far.z + near.z)/(far.z - near.z),
    0.0, 0.0, 0.0,                         (far.w + near.w)/(far.w - near.w)
  );
  float k = 2.0 * near.w * far.w / (far.w - near.w);
  vec4 q = m * p;
  q.w -= k;
  q /= p.w;
  vec4 v = vec4(10000.0, 10000.0, 10000.0, 1.0); // way off-screen
  float r2 = dot(p0,p0) * 0.5;
  float s = 0.0;
  if (r2 < 1.0) {
    s = sqrt(1.0 - r2);
    v = gl_ModelViewProjectionMatrix * q;
    v.xy += delta * s;
    ignore = 0.0;
  } else {
    ignore = 1.0;
  }
  gl_TexCoord[0] = gl_MultiTexCoord0;
  gl_Position = v;
  spin2 = spin;
  scale2 = 2.0 * length(delta) * s;
  pick2 = pick;
}
```

78 src/rdex.c

```
/* ==========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010,2017,2019  Claude Heiland-Allen <claude@mathr.co.uk>
---------------------------------------------------------------------------
Main Module
========================================================================== */

#define _DEFAULT_SOURCE

#include <math.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include "rdex.h"

//==========================================================================
// main module global mutable state
static struct rdex rdex;
```

```
20  //============================================================
    // main module initialization
    int rdex_init() {
      int nrt = 0 != getenv("RDEX_RENDER");
      memset(&rdex, 0, sizeof(rdex));
25    glGenFramebuffersEXT(1, &rdex.fbo);
      glClampColorARB( GL_CLAMP_VERTEX_COLOR_ARB , GL_FALSE );
      glClampColorARB( GL_CLAMP_FRAGMENT_COLOR_ARB, GL_FALSE );
      glClampColorARB( GL_CLAMP_READ_COLOR_ARB , GL_FALSE );
      if (! reactiondiffusion_init(&rdex.reactiondiffusion)) { return 0; }
30    if (! copysquare_init       (&rdex.copysquare       )) { return 0; }
      if (! arithmeticmean_init   (&rdex.arithmeticmean   )) { return 0; }
      if (! numericerror_init     (&rdex.numericerror     )) { return 0; }
      if (! difference_init       (&rdex.difference       )) { return 0; }
      if (! falsecolour_init      (&rdex.falsecolour      )) { return 0; }
35    if (! library_init          (&rdex.library, rdex.fbo)) { return 0; }
      if (! screenshot_init       (&rdex.screenshot, nrt  )) { return 0; }
      if (! audio_init            (&rdex.audio, nrt       )) { return 0; }
    //  if (! sequence_init         (&rdex.sequence         )) { return 0; }
      if (! intro_init            (&rdex.intro            )) { return 0; }
40    if (! timeline_init         (&rdex.timeline         )) { return 0; }
      if (! text_init             (&rdex.text             )) { return 0; }
      rdex.starttime = 0;
      rdex.fullscreen = 0;
    //  reactiondiffusion_spawn(&rdex.reactiondiffusion);
45    rdex.done = 0;
      rdex.behaviour = "none";
    #if 1
      rdex.mode = mode_random;
    #else
50    rdex.mode = mode_textual;
    #endif
      rdex.nrt = nrt;
      return 1;
    }
55
    //============================================================
    // main module reshape callback
    void rdex_reshape(int w, int h) {
      reactiondiffusion_reshape(&rdex.reactiondiffusion, rdex_tex_size, ↙
          ↳ rdex_tex_size);
60    copysquare_reshape       (&rdex.copysquare,        rdex_tex_size, ↙
          ↳ rdex_tex_size);
      arithmeticmean_reshape   (&rdex.arithmeticmean,    rdex_tex_size, ↙
          ↳ rdex_tex_size);
      numericerror_reshape     (&rdex.numericerror,      rdex_tex_size, ↙
          ↳ rdex_tex_size);
      difference_reshape       (&rdex.difference,        rdex_tex_size, ↙
          ↳ rdex_tex_size);
      falsecolour_reshape      (&rdex.falsecolour,       rdex_tex_size, ↙
          ↳ rdex_tex_size);
65    library_reshape          (&rdex.library,           w, h);
      screenshot_reshape       (&rdex.screenshot,        w, h);
    //  sequence_reshape         (&rdex.sequence,          w, h);
      intro_reshape            (&rdex.intro,             w, h);
      text_reshape             (&rdex.text,              w, h);
70  }
```

```
//============================================================================
// main module display callback
void rdex_display() {
  if (rdex.timeline.state1 != rdex.timeline.state) {
    switch (rdex.timeline.state) {
      case timeline_intro1:
        intro_start(&rdex.intro);
        audio_start(&rdex.audio);
        break;
      case timeline_intro2:
        rdex.library.phase = 0;
        rdex.library.state = library_state_intro;
        break;
      case timeline_main:
        rdex.library.phase = 0;
        rdex.library.state = library_state_active;
        break;
      case timeline_outro:
        rdex.library.phase = 0;
        rdex.library.state = library_state_outro;
        audio_stop(&rdex.audio);
        break;
      case timeline_done:
        rdex.library.phase = 0;
        rdex.library.state = library_state_done;
        break;
      case timeline_idle:
        break;
    }
  }
  timeline_advance(&rdex.timeline);
  glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, rdex.fbo);
  screenshot_display1       (&rdex.screenshot);
  for (int g = 0; g < rdex_overdrive; ++g) {
    reactiondiffusion_display(&rdex.reactiondiffusion, rdex.fbo);
    if (g % 2 == 0) {
      audio_display1        (&rdex.audio,              rdex.fbo, rdex.↙
          ↪ reactiondiffusion.texture, g / 2);
    }
  }
  copysquare_display        (&rdex.copysquare,         rdex.fbo, rdex.↙
      ↪ reactiondiffusion.texture);
  arithmeticmean_display    (&rdex.arithmeticmean,     rdex.fbo, rdex.copysquare ↙
      ↪       .texture);
  numericerror_display      (&rdex.numericerror,       rdex.fbo, rdex.↙
      ↪ reactiondiffusion.texture);
  difference_display        (&rdex.difference,         rdex.fbo, rdex.↙
      ↪ reactiondiffusion.texture);
  falsecolour_display       (&rdex.falsecolour,        rdex.fbo, rdex.↙
      ↪ reactiondiffusion.texture);
  library_display_save(
    &rdex.library,
    rdex.fbo,
    rdex.falsecolour.texture,
    rdex.reactiondiffusion.texture,
    rdex.reactiondiffusion.value.ru,
```

```
    rdex.reactiondiffusion.value.rv,
    rdex.reactiondiffusion.value.f,
    rdex.reactiondiffusion.value.k,
    (rdex.reactiondiffusion.frame / (double) (1 << 14)) *
    (rdex.reactiondiffusion.frame / (double) (1 << 14)),
    rdex.behaviour
  );
  library_display          (&rdex.library,          rdex.fbo, rdex.falsecolour.texture);
  if (rdex.library.picked != -1) {
    rdex.reactiondiffusion.value.ru = rdex.library.array[rdex.library.picked].v[0];
    rdex.reactiondiffusion.value.rv = rdex.library.array[rdex.library.picked].v[1];
    rdex.reactiondiffusion.value.f  = rdex.library.array[rdex.library.picked].v[2];
    rdex.reactiondiffusion.value.k  = rdex.library.array[rdex.library.picked].v[3];
    rdex.library.target.v[0] = rdex.library.array[rdex.library.picked].v[0];
    rdex.library.target.v[1] = rdex.library.array[rdex.library.picked].v[1];
    rdex.library.target.v[2] = rdex.library.array[rdex.library.picked].v[2];
    rdex.library.target.v[3] = rdex.library.array[rdex.library.picked].v[3];
    rdex.library.picked = -1;
  }

//  sequence_display         (&rdex.sequence, &rdex.library, &rdex.reactiondiffusion, &rdex.audio);
  text_display             (&rdex.text);
  intro_display            (&rdex.intro, 0.04); /* FIXME hardcoded frame rate */
  glutSwapBuffers();
  audio_display2           (&rdex.audio);
  screenshot_display2      (&rdex.screenshot);
  rdex.frame += 1;
  int reseed = rdex.done;
  if (rdex.done) {
    float ru = 0, rv = 0, f = 0, k = 0, ru2, rv2, f2, k2;
    switch (rdex.mode) {
    case mode_random: {
      int i = 0;
      float randomness = 1e6; //16.0;
      while (! library_pick(&rdex.library, &ru2, &rv2, &f2, &k2, randomness)) {
        ru += ru2;
        rv += rv2;
        f  += f2;
        k  += k2;
        i  += 1;
//      randomness = 2.0;
      }
      if (i == 0) {
        reactiondiffusion_randomize(&rdex.reactiondiffusion);
      } else {
        ru /= i;
        rv /= i;
        f  /= i;
        k  /= i;
        reactiondiffusion_near(&rdex.reactiondiffusion, ru, rv, f, k, 0.01);
      }
```

```
      rdex.audio.sphase = 0;
    } break;
    case mode_textual: {
      if (reseed) { rdex.reactiondiffusion.frame = 0; }
    } break;
    case mode_sequence: {
      if (reseed) { rdex.reactiondiffusion.frame = 0; }
    /*
      if (reseed) {
      float randomness = 1.1;
      if (! library_pick(&rdex.library, &ru, &rv, &f, &k, randomness)) {
        rdex.loop[rdex.loopindex].v[0] = ru;
        rdex.loop[rdex.loopindex].v[1] = rv;
        rdex.loop[rdex.loopindex].v[2] = f;
        rdex.loop[rdex.loopindex].v[3] = k;
      } else { //if (randomness * rand() / (double) RAND_MAX < 1.0) {
        rdex.loop[rdex.loopindex].v[0] = 0.3 * rand() / (double) RAND_MAX;
        rdex.loop[rdex.loopindex].v[1] = 0.3 * rand() / (double) RAND_MAX;
        rdex.loop[rdex.loopindex].v[2] = 0.1 * rand() / (double) RAND_MAX;
        rdex.loop[rdex.loopindex].v[3] = 0.1 * rand() / (double) RAND_MAX;
      }
    }
      ru = rdex.loop[rdex.loopindex].v[0];
      rv = rdex.loop[rdex.loopindex].v[1];
      f  = rdex.loop[rdex.loopindex].v[2];
      k  = rdex.loop[rdex.loopindex].v[3];
      if (reseed) {
        reactiondiffusion_near(&rdex.reactiondiffusion, ru, rv, f, k, 0.001);
      } else {
        rdex.reactiondiffusion.value.ru = ru;
        rdex.reactiondiffusion.value.rv = rv;
        rdex.reactiondiffusion.value.f  = f;
        rdex.reactiondiffusion.value.k  = k;
      }
      fprintf(stderr, "L\t");
    */
    } break;
    }
    rdex.library.worldsphere.delta[0] = (rand() / (double) RAND_MAX - 0.5) / ↙
        ↪ 64.0;
    rdex.library.worldsphere.delta[1] = (rand() / (double) RAND_MAX - 0.5) / ↙
        ↪ 64.0;
    rdex.done = 0;
  }
  glutReportErrors();
  if (rdex.library.state == library_state_active)
    rdex.audio.state = audio_state_rolling;
  if (rdex.timeline.state == timeline_idle)
    timeline_start(&rdex.timeline);
}

//=============================================================================
// main module exit callback
void rdex_atexit(void) {
// /* not safe to call at exit it seems... */
//   if (glutGameModeGet(GLUT_GAME_MODE_ACTIVE)) {
//     glutLeaveGameMode();
```

```
//  }
  audio_atexit(&rdex.audio);
  double timeelapsed = (double) time(NULL) - (double) rdex.starttime;
  fprintf(stderr, "\n\n↙
      ↪ ------------------------------------------------------------------------\↙
      ↪ n");
  fprintf(stderr, "------------------------------ statistics ↙
      ↪ -------------------------------\n");
  fprintf(stderr, ↙
      ↪ "------------------------------------------------------------------------\↙
      ↪ n");
  fprintf(stderr, "%10d seconds elapsed (+/- 1)\n", (int) timeelapsed);
  fprintf(stderr, "%10d frames rendered (%f fps)\n", rdex.frame, rdex.frame / ↙
      ↪ timeelapsed);
  fprintf(stderr, "%10d frames dropped\n", (int) (25 * timeelapsed - rdex.frame)↙
      ↪ );
  fprintf(stderr, "%10d species analyzed (%f sps)\n", rdex.species, rdex.species↙
      ↪  / timeelapsed);
  fprintf(stderr, "        %6.2f%% uniform (%d)\n", 100.0 * rdex.uniform / (↙
      ↪ double) rdex.species, rdex.uniform);
  fprintf(stderr, "        %6.2f%% stable  (%d)\n", 100.0 * rdex.stable  / (↙
      ↪ double) rdex.species, rdex.stable);
  fprintf(stderr, "        %6.2f%% dynamic (%d)\n", 100.0 * rdex.dynamic / (↙
      ↪ double) rdex.species, rdex.dynamic);
  fprintf(stderr, "        %6.2f%% erratic (%d)\n", 100.0 * rdex.erratic / (↙
      ↪ double) rdex.species, rdex.erratic);
  fprintf(stderr, ↙
      ↪ "------------------------------------------------------------------------\↙
      ↪ n");
  fprintf(stderr, "average frame time: %f seconds\n", rdex.sumdt / rdex.sum1);
  fprintf(stderr, "standard deviation: %f\n", sqrt( rdex.sumdt2 / rdex.sum1 - ↙
      ↪ pow(rdex.sumdt / rdex.sum1, 2) ));
  fprintf(stderr, ↙
      ↪ "------------------------------------------------------------------------\↙
      ↪ n");
}

//=============================================================
// main module timer callback
//void rdex_idle() {
void rdex_timer(int v) {

  // initialize
  if (rdex.starttime == 0) {
    rdex.starttime = time(NULL);
    rdex.frame = 0;
    rdex.sum1 = 0;
    rdex.sumdt = 0;
    rdex.sumdt2 = 0;
    atexit(rdex_atexit);
    clock_gettime(CLOCK_REALTIME, &rdex.clock0);
  }

  // check if there are enough free buffers to render a frame
  int r = audio_read;
  int w = audio_write;
  if (rdex.nrt || (w < r && w + AUDIO_COUNT < r) || ( r < w && w + AUDIO_COUNT <↙
```

```
      ↪  r + AUDIO_BUFFERS)) {

  for (int g = 0; g < rdex_overdrive; ++g) {
    reactiondiffusion_idle(&rdex.reactiondiffusion);
  }
  copysquare_idle       (&rdex.copysquare);
  arithmeticmean_idle   (&rdex.arithmeticmean);
  numericerror_idle     (&rdex.numericerror);
  difference_idle       (&rdex.difference);
  falsecolour_idle      (&rdex.falsecolour);
  library_idle          (&rdex.library);
  screenshot_idle       (&rdex.screenshot);
  if (rdex.reactiondiffusion.frame > (rdex_count*1) && rdex.arithmeticmean.↙
      ↪ stddev < 0.01) {
//    if (rdex.species % 32 == 0) {
//      if (rdex.species) { fputc('|', stderr); }
//      fprintf(stderr, "\n%08x|", rdex.species);
//    }
    rdex.done = 1; //(rdex.mode == mode_random);
    rdex.species += 1;
    rdex.uniform += 1;
    rdex.behaviour = "uniform";
//    rdex.library.snap = 1;
    //fprintf(stderr, "_\t%d", rdex.reactiondiffusion.frame);
//    reactiondiffusion_randomize(&rdex.reactiondiffusion);
  } else if (rdex.reactiondiffusion.frame % (rdex_count*2) == (rdex_count*1)) {
    rdex.numericerror.calc = 1;
  } else if (rdex.reactiondiffusion.frame % (rdex_count*2) == (rdex_count*1) + ↙
      ↪ rdex_overdrive) {
    if (rdex.numericerror.mean > 0.2) {
//      if (rdex.species % 32 == 0) {
//        if (rdex.species) { fputc('|', stderr); }
//        fprintf(stderr, "\n%08x|", rdex.species);
//      }
      rdex.done = 1;
      rdex.species += 1;
      rdex.erratic += 1;
      //fprintf(stderr, ".\t%d", rdex.reactiondiffusion.frame);
      //reactiondiffusion_randomize(&rdex.reactiondiffusion);
    }
  } else if (rdex.reactiondiffusion.frame % (rdex_count*3) == (rdex_count*1)) {
    rdex.difference.snap = 1;
  } else if (rdex.reactiondiffusion.frame % (rdex_count*3) == (rdex_count*2)) {
    rdex.difference.calc = 1;
  } else if (rdex.reactiondiffusion.frame % (rdex_count*3) == (rdex_count*2) + ↙
      ↪ rdex_overdrive) {
    if (rdex.difference.mean < 0.011) {
      rdex.done = (rdex.mode == mode_random);
      rdex.species += 1;
      rdex.stable += 1;
      rdex.behaviour = "stable";
      rdex.library.snap = (rdex.mode == mode_random);
      //fprintf(stderr, "o\t%d", rdex.reactiondiffusion.frame);
    } else if (rdex.reactiondiffusion.frame > 16000 && rdex.mode == mode_random)↙
        ↪ {
      rdex.done = 1;
      rdex.species += 1;
```

```
320         rdex.dynamic += 1;
            rdex.behaviour = "dynamic";
            rdex.library.snap = (rdex.mode == mode_random);
            //fprintf(stderr, "*\t%d", rdex.reactiondiffusion.frame);
          }
325       }
      /* else if (rdex.reactiondiffusion.frame == 14400) {
          if (rdex.species % 32 == 0) {
            if (rdex.species) { fputc('|', stderr); }
            fprintf(stderr, "\n%08x|", rdex.species);
330         }
          rdex.species += 1;
          int which = rdex.difference.mean < 0.01;
          if (which) { rdex.stable += 1; } else { rdex.dynamic += 1; }
          fputc(which ? 'o' : '*', stderr);
335       //reactiondiffusion_perturb(&rdex.reactiondiffusion);
          reactiondiffusion_randomize(&rdex.reactiondiffusion);
        }
      */
        glutPostRedisplay();
340

        // gather timing statistics
        clock_gettime(CLOCK_REALTIME, &rdex.clock1);
        double dt = (rdex.clock1.tv_sec - rdex.clock0.tv_sec) + 1.0e-9 * (rdex.clock1.↙
            ↳ tv_nsec - rdex.clock0.tv_nsec);
345     rdex.sum1 += 1;
        rdex.sumdt += dt;
        rdex.sumdt2 += dt*dt;
        clock_gettime(CLOCK_REALTIME, &rdex.clock0);

350     }

        // sleep for 1ms and check again if jack is ready
        glutTimerFunc(1, rdex_timer, v + 1);

355   }

      void rdex_pmotion(int x, int y) {
        library_pmotion(&rdex.library, x, y);
      }
360
      void rdex_amotion(int x, int y) {
        library_amotion(&rdex.library, x, y);
      }

365   void rdex_mouse(int button, int state, int x, int y) {
        library_mouse(&rdex.library, button, state, x, y);
      }

      void rdex_keynormal(unsigned char key, int x, int y) {
370     return;
        if (text_keynormal(&rdex.text, key, x, y)) {
          if (key == ' ') {
            struct libelem *e = &rdex.library.array[rand() % (rdex.library.count - 1)↙
                ↳ ];
            rdex.reactiondiffusion.value.ru = e->v[0];
```

```
        rdex.reactiondiffusion.value.rv = e->v[1];
        rdex.reactiondiffusion.value.f  = e->v[2];
        rdex.reactiondiffusion.value.k  = e->v[3];
          }
      reactiondiffusion_perturb(&rdex.reactiondiffusion);
    } else {
//  if (! sequence_keynormal(&rdex.sequence, &rdex.library, key, x, y)) {
          switch (key) {
                  case 27: // escape
                                  exit(0);
                    break;
                  case 9: // tab
        timeline_start(&rdex.timeline);
//                  audio_start(&rdex.audio);
//        intro_start(&rdex.intro);
                    break;
                  case 127: // delete
        timeline_stop(&rdex.timeline);
//                  audio_stop(&rdex.audio);
        //outro_start(&rdex.outro);
                    break;
                  default:
                    break;
          }
  }
}

void rdex_keyspecial(int key, int x, int y) {
return;
//  if (! sequence_keyspecial(&rdex.sequence, &rdex.library, key, x, y)) {
    if (! text_keyspecial(&rdex.text, key, x, y)) {
    switch (key) {
            default:
              break;
    }
  }
}

// EOF
```

79 src/rdex.ds

```
(begin

(if (is (application_name) "rdex")
  (begin
    (pin)
    (undecorate)
    (above)
    (geometry "1024x768+0+0")
  )
)
(if (is (application_name) "meterbridge")
  (begin
    (geometry "74x210+770+30")
  )
)
```

```
(if (contains (window_name) "JACK Audio Connection Kit [(default)]")
  (begin
    (geometry "500x110+860+30")
  )
)
(if (is (window_name) "Connections - JACK Audio Connection Kit")
  (begin
    (geometry "500x210+860+160")
  )
)
(if (is (window_name) "JACK Rack (rdex) - rdex.jr")
  (begin
    (geometry "500x160+860+400")
  )
)
(if (is (window_name) "top")
  (begin
    (geometry "500x160+860+590")
  )
)

)
```

80 src/rdex.h

```
/* ==========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------
Main Module
========================================================================== */

#ifndef RDEX_H
#define RDEX_H 1

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

#include "reactiondiffusion.h"
#include "copysquare.h"
#include "arithmeticmean.h"
#include "numericerror.h"
#include "difference.h"
#include "falsecolour.h"
#include "library.h"
#include "screenshot.h"
#include "audio.h"
#include "sequence.h"
#include "intro.h"
#include "timeline.h"
#include "text.h"

//==========================================================================
// configuration
#define rdex_tex_size 256
// FIXME: breakage will occur when rdex_count % rdex_overdrive != 0
```

```
// FIXME: check audio when audioHz % videoHz != 0
// FIXME: check audio when overdrive % (audioHz / videoHz) != 0
#define rdex_count 96
// FIXME optimal overdrive depends on sample rate!
//   14   * 25 * 126 = 44100
//   16   * 25 * 120 = 48000
#define rdex_overdrive (AUDIO_COUNT * 2)
//#define rdex_videoHz 33

enum rdex_mode {
  mode_random = 100, mode_textual, mode_sequence
};

//======================================================================
// main module data
struct rdex {
  struct reactiondiffusion reactiondiffusion;
  struct copysquare        copysquare;
  struct arithmeticmean    arithmeticmean;
  struct numericerror      numericerror;
  struct difference        difference;
  struct falsecolour       falsecolour;
  struct library           library;
  struct screenshot        screenshot;
  struct audio             audio;
//  struct sequence          sequence;
  struct intro             intro;
  struct timeline          timeline;
  struct text              text;
  GLuint fbo;
  time_t starttime;
  struct timespec clock0, clock1;
  unsigned int frame;
  unsigned int framedrops;
  unsigned int species;
  unsigned int uniform;
  unsigned int stable;
  unsigned int dynamic;
  unsigned int erratic;
  int done;
  int fullscreen;
  char *behaviour;
  enum rdex_mode mode;
  int nrt;
  // timing statistics
  double sum1, sumdt, sumdt2;
};

//======================================================================
// prototypes
int rdex_init(void);
void rdex_reshape(int w, int h);
void rdex_display(void);
void rdex_atexit(void);
void rdex_timer(int v);
//void rdex_idle();
void rdex_pmotion(int x, int y);
```

```
90  void rdex_amotion(int x, int y);
    void rdex_mouse(int button, int state, int x, int y);
    void rdex_keynormal(unsigned char key, int x, int y);
    void rdex_keyspecial(int key, int x, int y);

95  #endif
```

81 src/rdex-logo-128x128.ppm

82 src/rdex-logo-32x32.xpm

```
    /* XPM */
    static char * rdex_logo_32x32_xpm[] = {
    "32 32 103 2",
    "       c None",
 5  ".      c #352D0C",
    "+      c #765F04",
    "@      c #A38300",
    "#      c #B69200",
    "$      c #A48300",
10  "%      c #776005",
    "&      c #372F0D",
    "*      c #221E0D",
    "=      c #927501",
    "-      c #F8C700",
15  ";      c #FFCC00",
    ">      c #F9C700",
    ",      c #947701",
    "'      c #262314",
    ")      c #5C4B06",
20  "!      c #E3B600",
    "~      c #CBA200",
    "{      c #2B2610",
    "]      c #252114",
```

```
"^      c #9E7E01",
"/      c #FECB00",
"(      c #B49000",
"_      c #362D0B",
":      c #CFA500",
"<      c #604E05",
"[      c #44390D",
"}      c #E5B700",
"|      c #C49D00",
"1      c #6B5706",
"2      c #68550A",
"3      c #AC8900",
"4      c #BB9600",
"5      c #44380B",
"6      c #EBBC00",
"7      c #EEBF00",
"8      c #6D5804",
"9      c #977902",
"0      c #F5C400",
"a      c #1B180D",
"b      c #352B07",
"c      c #E6B800",
"d      c #C8A000",
"e      c #372E0B",
"f      c #3A310E",
"g      c #372F0E",
"h      c #26210D",
"i      c #D4AA00",
"j      c #A68400",
"k      c #211E13",
"l      c #201B07",
"m      c #30290B",
"n      c #A98701",
"o      c #6B5604",
"p      c #EDBE00",
"q      c #1B1A13",
"r      c #6A5605",
"s      c #A18100",
"t      c #0B0A05",
"u      c #171408",
"v      c #675406",
"w      c #F1C000",
"x      c #A98800",
"y      c #2D260A",
"z      c #ECBD00",
"A      c #F4C300",
"B      c #F1C100",
"C      c #F6C500",
"D      c #4E410C",
"E      c #9C7D01",
"F      c #927502",
"G      c #3E3308",
"H      c #FCC900",
"I      c #A58402",
"J      c #A38301",
"K      c #DFB300",
"L      c #6E5905",
```

```
"M  c #342C0C",
"N  c #F8C600",
"O  c #C7A000",
"P  c #15130B",
"Q  c #806704",
"R  c #A78600",
"S  c #362C03",
"T  c #E4B600",
"U  c #A28200",
"V  c #D3A900",
"W  c #4F410A",
"X  c #372C02",
"Y  c #3D330B",
"Z  c #352B02",
"`  c #745E06",
" . c #866B02",
".. c #51430A",
"+. c #6E5A09",
"@. c #D6AB00",
"#. c #1A1811",
"$. c #7C650A",
"%. c #1D1A0E",
"&. c #C9A100",
"*. c #24200D",
"=. c #6D5700",
"-. c #53440A",
"                                                                ",
"                                                                ",
"                                                                ",
"                                                                ",
"                                    . + @ # $ % &               ",
"                                * = - ; ; ; ; ; > , '           ",
"                              ) ! ; ; ; ; ; ; ; ; ; ~ {         ",
"                          ] ^ / ; ; ; ; ; ; ; ; ; ; ; (         ",
"                        _ : ; ; ; ; ; ; ; ; ; ; ; ; ; ; <       ",
"                      [ } ; ; ; ; ; ; | 1 2 3 ; ; ; ; ; 4       ",
"                    5 6 ; ; ; ; ; 7 8         9 ; ; ; ; 0 a     ",
"                  b c ; ; ; ; ; d e           f ; ; ; ; ; g     ",
"                h i ; ; ; ; ; j k             l ; ; ; ; ; m     ",
"                n ; ; ; ; ; 9                 o ; ; ; ; p q     ",
"              r ; ; ; ; ; s t             u v w ; ; ; ; x       ",
"            y z ; ; ; ; ; A B B B B B B B C ; ; ; ; ; / D       ",
"            E ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; F         ",
"          G H ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; I           ",
"          J ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; ; K L             ",
"        M N ; ; ; H | | | | | | | 6 ; ; ; ; ; O P               ",
"        Q ; ; ; ; R               S T ; ; ; ; ; U               ",
"        V ; ; ; ; W                 X T ; ; ; ; ; U             ",
"      Y ; ; ; ; i                     Z T ; ; ; ; ; U           ",
"      ` ; ; ; ;  .                      X T ; ; ; ; ; U         ",
"      $ ; ; ; ; ..                        Z T ; ; ; ; ; +.      ",
"      @.; ; ; C #.                          X T ; ; ; ; $.      ",
"    %.C ; ; ; &.                              Z T ; ; ; $.      ",
"    *.$ $ $ $ =.                                X s $ $ -.      ",
"                                                                ",
"                                                                ",
"                                                                ",
```

```
"                                                                    "};
```

83 src/reactiondiffusion.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009,2010,2019  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Reaction Diffusion Shader
================================================================ */

#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include "util.h"
#include "reactiondiffusion.h"
#include "reactiondiffusion.frag.c"

//================================================================
// reaction diffusion shader parameter randomization
void reactiondiffusion_randomize(
  struct reactiondiffusion *reactiondiffusion
) {
  reactiondiffusion->value.ru = 0.3*rand() / (double) RAND_MAX + 0.001;
  reactiondiffusion->value.rv = 0.3*rand() / (double) RAND_MAX + 0.001;
  reactiondiffusion->value.f  = 0.1*rand() / (double) RAND_MAX + 0.001;
  reactiondiffusion->value.k  = 0.1*rand() / (double) RAND_MAX + 0.001;
  reactiondiffusion->frame = 0;
#if 0
  fprintf(stderr, "\n%f\t%f\t%f\t%f\t",
    reactiondiffusion->value.ru,
    reactiondiffusion->value.rv,
    reactiondiffusion->value.f,
    reactiondiffusion->value.k
  );
#endif
}
/*
  reactiondiffusion->spawnangle += 1.0 / 32.0;
  double a = reactiondiffusion->spawnangle;
  reactiondiffusion->value.ru = (cos(sqrt(2) * a) * 0.5 + 0.5) * 0.01 + 0.15;
  reactiondiffusion->value.rv = (cos(sqrt(3) * a) * 0.5 + 0.5) * 0.01 + 0.15;
  reactiondiffusion->value.f  = (sin(sqrt(5) * a) * 0.5 + 0.5) * 0.01 + 0.001;
  reactiondiffusion->value.k  = (sin(sqrt(7) * a) * 0.5 + 0.5) * 0.01 + 0.001;
*/

void reactiondiffusion_near(
  struct reactiondiffusion *reactiondiffusion, float ru, float rv, float f, ↙
    ↳ float k, float d
) {
  reactiondiffusion->value.ru = ru + d * 0.3*(rand() / (double) RAND_MAX - 0.5);
  reactiondiffusion->value.rv = rv + d * 0.3*(rand() / (double) RAND_MAX - 0.5);
  reactiondiffusion->value.f  = f  + d * 0.1*(rand() / (double) RAND_MAX - 0.5);
  reactiondiffusion->value.k  = k  + d * 0.1*(rand() / (double) RAND_MAX - 0.5);
  reactiondiffusion->frame = 0;
  fprintf(stderr, "\n%f\t%f\t%f\t%f\t",
  reactiondiffusion->value.ru,
```

```
    reactiondiffusion->value.rv,
    reactiondiffusion->value.f,
    reactiondiffusion->value.k
  );
}

//=============================================================================
// reaction diffusion shader parameter perturbation
void reactiondiffusion_perturb(
  struct reactiondiffusion *reactiondiffusion
) {
  reactiondiffusion->value.ru += 0.003 * (rand() / (double) RAND_MAX - 0.5);
  reactiondiffusion->value.rv += 0.003 * (rand() / (double) RAND_MAX - 0.5);
  reactiondiffusion->value.f  += 0.003 * (rand() / (double) RAND_MAX - 0.5);
  reactiondiffusion->value.k  += 0.003 * (rand() / (double) RAND_MAX - 0.5);
#define clip(x,m,M) ((x)=(((x)<(m))?(m):(((x)>(M))?(M):(x))))
  clip(reactiondiffusion->value.ru, 0.0, 0.3);
  clip(reactiondiffusion->value.rv, 0.0, 0.3);
  clip(reactiondiffusion->value.f,  0.0, 0.1);
  clip(reactiondiffusion->value.k,  0.0, 0.1);
#undef clip
//  reactiondiffusion->frame = 0;
}

//=============================================================================
// reaction diffusion shader initialization
struct reactiondiffusion *reactiondiffusion_init(
  struct reactiondiffusion *reactiondiffusion
) {
  if (! reactiondiffusion) { return 0; }
  if (! shader_init(
          &reactiondiffusion->shader, 0, reactiondiffusion_frag
    )) {
    return 0;
  }
  shader_uniform(reactiondiffusion, texture);
  shader_uniform(reactiondiffusion, dx);
  shader_uniform(reactiondiffusion, dy);
  shader_uniform(reactiondiffusion, ru);
  shader_uniform(reactiondiffusion, rv);
  shader_uniform(reactiondiffusion, f);
  shader_uniform(reactiondiffusion, k);
  reactiondiffusion->value.texture = 0;
  reactiondiffusion->value.dx      = 0;
  reactiondiffusion->value.dy      = 0;
  reactiondiffusion->spawnangle = 0.0;
  reactiondiffusion->frame = 0;
  reactiondiffusion_randomize(reactiondiffusion);
  glGenTextures(2, reactiondiffusion->textures);
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, reactiondiffusion->textures[0]);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  glBindTexture(GL_TEXTURE_2D, reactiondiffusion->textures[1]);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);
  glDisable(GL_TEXTURE_2D);
```

```
  reactiondiffusion->buffer = 0;
  reactiondiffusion->width  = 0;
  reactiondiffusion->height = 0;
  reactiondiffusion->seed   = 60;
  return reactiondiffusion;
}

//=============================================================
// reaction diffusion shader reshape callback
void reactiondiffusion_reshape(
  struct reactiondiffusion *reactiondiffusion, int w, int h
) {
  reactiondiffusion->width  = roundtwo(w);
  reactiondiffusion->height = roundtwo(h);
  reactiondiffusion->value.dx = 1.0 / reactiondiffusion->width;
  reactiondiffusion->value.dy = 1.0 / reactiondiffusion->height;
  float *zero = calloc(1, reactiondiffusion->width * reactiondiffusion->height *↙
      ↳ 2 * sizeof(float));
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, reactiondiffusion->textures[0]);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RG32F,
    reactiondiffusion->width, reactiondiffusion->height,
    0, GL_RG, GL_FLOAT, zero
  );
  glBindTexture(GL_TEXTURE_2D, reactiondiffusion->textures[1]);
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RG32F,
    reactiondiffusion->width, reactiondiffusion->height,
    0, GL_RG, GL_FLOAT, zero
  );
  free(zero);
  glDisable(GL_TEXTURE_2D);
}

//=============================================================
// reaction diffusion shader display callback
void reactiondiffusion_display(
  struct reactiondiffusion *reactiondiffusion, GLuint fbo
) {
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D,
    reactiondiffusion->textures[reactiondiffusion->buffer]
  );
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
  glFramebufferTexture2DEXT(
    GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT, GL_TEXTURE_2D,
    reactiondiffusion->textures[1 - reactiondiffusion->buffer], 0
  );
  glUseProgramObjectARB(reactiondiffusion->shader.program);
  shader_updatei(reactiondiffusion, texture);
  shader_updatef(reactiondiffusion, dx);
  shader_updatef(reactiondiffusion, dy);
  shader_updatef(reactiondiffusion, ru);
  shader_updatef(reactiondiffusion, rv);
  shader_updatef(reactiondiffusion, f);
  shader_updatef(reactiondiffusion, k);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
```

```
  gluOrtho2D(0, 1, 0, 1);
  glMatrixMode(GL_MODELVIEW);
  glLoadIdentity();
  glViewport(0, 0, reactiondiffusion->width, reactiondiffusion->height);
  glBegin(GL_QUADS); { glColor4f(1,1,1,1);
    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);
  glDisable(GL_TEXTURE_2D);
  if (reactiondiffusion->frame < reactiondiffusion->seed) {
    if (reactiondiffusion->frame == 0) {
      glBegin(GL_QUADS); {
        glColor4f(0.5,0.5,0.5,1);
        glVertex2f(0, 0);
        glVertex2f(1, 0);
        glVertex2f(1, 1);
        glVertex2f(0, 1);
      } glEnd();
    }
    glEnable(GL_POLYGON_SMOOTH);
    glBegin(GL_QUADS); { for (int q = 0; q < reactiondiffusion->seed - ↙
        ↳ reactiondiffusion->frame; ++q) {
      float u = (double) rand() / (double) RAND_MAX;
      float v = (double) rand() / (double) RAND_MAX;
      glColor4f(u,v,0,1); //(0,1,0,1);
      float x = (double) rand() / (double) RAND_MAX;
      float y = (double) rand() / (double) RAND_MAX;
      float w = ((double) rand() / (double) RAND_MAX - 0.5) / 16.0;
      float h = ((double) rand() / (double) RAND_MAX - 0.5) / 16.0;
      float a = ((double) rand() / (double) RAND_MAX) * 2.0 * 3.1415926;
      float c = cos(a);
      float s = sin(a);
      for (int dx = -1; dx <= 1; dx += 1) {
        for (int dy = -1; dy <= 1; dy += 1) {
          glVertex2f(dx + x + w * c + h *  s, dy + y + w * -s + h * c);
          glVertex2f(dx + x + w * c + h * -s, dy + y + w * -s + h *-c);
          glVertex2f(dx + x + w *-c + h * -s, dy + y + w *  s + h *-c);
          glVertex2f(dx + x + w *-c + h *  s, dy + y + w *  s + h * c);
        }
      }
    } } glEnd();
    glDisable(GL_POLYGON_SMOOTH);
  }
  //glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
  glDisable(GL_TEXTURE_2D);
  reactiondiffusion->buffer = 1 - reactiondiffusion->buffer;
  reactiondiffusion->texture =
    reactiondiffusion->textures[reactiondiffusion->buffer];
}

//=============================================================================
// reaction diffusion shader idle callback
void reactiondiffusion_idle(
  struct reactiondiffusion *reactiondiffusion
```

```
) {
  reactiondiffusion->frame += 1;
}

// EOF
```

84 src/reactiondiffusion.frag

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2009  Claude Heiland-Allen <claude@mathr.co.uk>
============================================================================ */

uniform sampler2D texture; // U := r, V := g, other channels ignored
uniform float dx;          // horizontal distance between texels
uniform float dy;          // vertical distance between texels
uniform float ru;          // rate of diffusion of U
uniform float rv;          // rate of diffusion of V
uniform float f;           // some coupling parameter
uniform float k;           // another coupling parameter

void main(void) {
  float center = -(4.0+4.0/sqrt(2.0));  // -1 * other weights
  float diag   = 1.0/sqrt(2.0);        // weight for diagonals
  vec2 p = gl_TexCoord[0].st;              // center coordinates
  vec2 c = texture2D(texture, p).rg;       // center value
  vec2 l                                   // compute Laplacian
    =(texture2D(texture, p + vec2(-dx,-dy)).rg
    + texture2D(texture, p + vec2( dx,-dy)).rg
    + texture2D(texture, p + vec2(-dx, dy)).rg
    + texture2D(texture, p + vec2( dx, dy)).rg) * diag
    + texture2D(texture, p + vec2(-dx, 0.0)).rg
    + texture2D(texture, p + vec2( dx, 0.0)).rg
    + texture2D(texture, p + vec2(0.0,-dy)).rg
    + texture2D(texture, p + vec2(0.0, dy)).rg
    + c.rg * center;
  float u = c.r;                           // compute some temporary
  float v = c.g;                           // values which might save
  float lu = l.r;                          // a few GPU cycles
  float lv = l.g;
  float uvv = u * v * v;
  //============================================================
  float du = ru * lu - uvv + f * (1.0 - u); // Gray-Scott equation
  float dv = rv * lv + uvv - (f + k) * v; // diffusion+-reaction
  //============================================================
  u += 0.6*du; // semi-arbitrary scaling (reduces blow-ups?)
  v += 0.6*dv;
  gl_FragColor = vec4(clamp(u, 0.0, 1.0), clamp(v, 0.0, 1.0), 0.0, 1.0);
      ↪ // output new (U,V)
}
```

85 src/reactiondiffusion.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
```

```
    ------------------------------------------------------------------------
5   Reaction Diffusion Shader
    ======================================================================== */

    #ifndef REACTIONDIFFUSION_H
    #define REACTIONDIFFUSION_H 1
10
    #include "shader.h"

    //========================================================================
    // reaction diffusion shader data
15  struct reactiondiffusion { struct shader shader;
      struct { GLint texture; GLint dx, dy, ru, rv, f, k; } uniform;
      struct { int   texture; float dx, dy, ru, rv, f, k; } value;
      GLuint textures[2];
      GLuint texture;
20    int buffer;
      int width;
      int height;
      int seed;
      int frame;
25    double spawnangle;
    };

    //========================================================================
    // prototypes
30  void reactiondiffusion_randomize(
      struct reactiondiffusion *reactiondiffusion
    );
    void reactiondiffusion_near(
      struct reactiondiffusion *reactiondiffusion, float ru, float rv, float f, ↙
          ↳ float k, float d
35  );
    void reactiondiffusion_perturb(
      struct reactiondiffusion *reactiondiffusion
    );
    struct reactiondiffusion *reactiondiffusion_init(
40    struct reactiondiffusion *reactiondiffusion
    );
    void reactiondiffusion_reshape(
      struct reactiondiffusion *reactiondiffusion, int w, int h
    );
45  void reactiondiffusion_display(
      struct reactiondiffusion *reactiondiffusion, GLuint fbo
    );
    void reactiondiffusion_idle(
      struct reactiondiffusion *reactiondiffusion
50  );

    #endif
```

86 src/s2c.sh

```
#!/bin/bash
echo "/* machine-generated file, do not edit */"
echo "static const char $1[] = \"#extension GL_EXT_gpu_shader4 : enable\n\""
sed 's|//.*||' |
```

```
sed 's|^|"|' |
sed 's|$|"|'
echo ";"
```

87 src/screenshot.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010,2019  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Screenshot Module
================================================================ */

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <GL/glew.h>
#include "screenshot.h"

//================================================================
// screenshot data
struct screenshot_data {
  int width;
  int height;
  unsigned char *data;
};

// background consumer
void screenshot_output(struct screenshot *screenshot, size_t s, struct screenshot_data *sd) {
  if (sd && sd->data) {
    fprintf(stdout, "P6\n%d %d 255\n", sd->width, sd->height);
    for (int y = sd->height - 1; y >= 0; --y) {
      fwrite(sd->data + y * sd->width * 3, sd->width * 3, 1, stdout);
    }
    fflush(stdout);
    free(sd->data);
  }
}

//================================================================
// screenshot module initialization
struct screenshot *screenshot_init(struct screenshot *screenshot, int nrt) {
  if (! screenshot) { return 0; }
  screenshot->nrt = nrt;
  screenshot->rate = 1; // FIXME use environment variable for this
  screenshot->frame = 0;
  screenshot->width = 0;
  screenshot->height = 0;
  screenshot->buffer = 0;
  // fbo
//  glGenFramebuffersEXT(1, &screenshot->fbo);
  // pbo
  glGenBuffersARB(1, &screenshot->pbo);
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, screenshot->pbo);
  glBufferDataARB(GL_PIXEL_PACK_BUFFER_ARB, 1024 * 768 * 3, 0, GL_STREAM_READ_ARB); // FIXME hardcoded
```

```
50    glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, 0);
      screenshot->ready = 0;
      // background output
    #if 0
      screenshot->queue = pfifo_create((pfifo_consumer *) screenshot_output, ↙
          ↳ screenshot);
55  #endif
      return screenshot;
    }

    //============================================================
60  // screenshot module display callbacks


    // save PBO data
    void screenshot_display1(struct screenshot *screenshot) {
65    if (! screenshot->ready) { return; }
      glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, screenshot->pbo);
      unsigned char *p = glMapBufferARB(GL_PIXEL_PACK_BUFFER_ARB, GL_READ_ONLY_ARB);
      if (p) {
        struct screenshot_data sd;
70      sd.width = screenshot->width;
        sd.height = screenshot->height;
        sd.data = malloc(sd.width * sd.height * 3);
        memcpy(sd.data, p, sd.width * sd.height * 3);
    #if 0
75      pfifo_enqueue(screenshot->queue, sizeof(struct screenshot_data), &sd);
    #endif
        if (! glUnmapBufferARB(GL_PIXEL_PACK_BUFFER_ARB)) {
          fprintf(stderr, "unmap buffer error\n");
        }
80  #if 1
        screenshot_output(screenshot, sizeof(struct screenshot_data), &sd);
    #endif
      }
      glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, 0);
85  }

    // copy frame to PBO and start download
    void screenshot_display2(struct screenshot *screenshot) {
      int fps = 25;
90    int rate = screenshot->rate;
      int frame = screenshot->frame;
      int period = 60 * 60 * fps * rate; // 60 minutes
      int interval = 5 * 60 * fps * rate; // 5 minutes
      if (screenshot->nrt && (frame % rate) == 0 && (frame % period) < interval) {
95      // copy framebuffer to PBO
        glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, screenshot->pbo);
        glReadPixels(0, 0, screenshot->width, screenshot->height, GL_RGB, ↙
            ↳ GL_UNSIGNED_BYTE, 0);
        glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, 0);
    /*
100     glReadPixels(0, 0, screenshot->width, screenshot->height, GL_RGB, ↙
            ↳ GL_UNSIGNED_BYTE, screenshot->buffer);
        fprintf(stdout, "P6\n%d %d 255\n", screenshot->width, screenshot->height);
        for (int y = screenshot->height - 1; y >= 0; --y) {
          fwrite(screenshot->buffer + y * screenshot->width * 3, screenshot->width *↙
```

```
        ↪ 3, 1, stdout);
    }
*/
    screenshot->ready = 1;
  } else {
    screenshot->ready = 0;
  }
  screenshot->frame += 1;
}

//=========================================================
// screenshot module reshape callback
void screenshot_reshape(struct screenshot *screenshot, int w, int h) {
  screenshot->width = w;
  screenshot->height = h;
  if (screenshot->buffer) free(screenshot->buffer);
  screenshot->buffer = malloc(w * h * 3);
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, screenshot->pbo);
  glBufferDataARB(GL_PIXEL_PACK_BUFFER_ARB, (w + 4) * h * 3, 0, ↙
      ↪ GL_STREAM_READ_ARB);
  glBindBufferARB(GL_PIXEL_PACK_BUFFER_ARB, 0);
}

//=========================================================
// screenshot module idle callback
void screenshot_idle(struct screenshot *screenshot) {
}

// EOF
```

88 src/screenshot.h

```
/* =========================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
-------------------------------------------------------------
Screenshot Module
========================================================= */

#ifndef SCREENSHOT_H
#define SCREENSHOT_H 1

#include "pfifo.h"

//=========================================================
// screenshot module data
struct screenshot {
  int nrt;
  int rate;
  int frame;
  int width;
  int height;
  char *buffer;
  GLuint pbo;
  int ready;
  struct pfifo *queue;
};
```

```
//=============================================================================
// prototypes
struct screenshot *screenshot_init(struct screenshot *screenshot, int nrt);
void screenshot_display1(struct screenshot *screenshot);
void screenshot_display2(struct screenshot *screenshot);
void screenshot_reshape(struct screenshot *screenshot, int w, int h);
void screenshot_idle(struct screenshot *screenshot);

#endif
```

89 src/segment.c

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
CPU-Based Image Segmentation
============================================================================ */

#include <math.h>
#include <stdlib.h>
#include "segment.h"
#include "util.h"

#define SEGMENT_LEVELS 4

struct segment_edge {
  int   fx,fy,tx,ty;
  float w;
};

static inline void segment_weight(struct segment_edge *e, const struct image *i)↙
    ↳ {
  e->w = fabs(I(i,e->fx,e->fy,0)-I(i,e->tx,e->ty,0))
       + fabs(I(i,e->fx,e->fy,1)-I(i,e->tx,e->ty,1))
       + fabs(I(i,e->fx,e->fy,2)-I(i,e->tx,e->ty,2));
}

static int segment_compare(const void *x, const void *y) {
  const struct segment_edge *e1 = x;
  const struct segment_edge *e2 = y;
  if (e1->w < e2->w) return -1;
  if (e1->w > e2->w) return 1;
  return 0;
}

struct segment_component {
  int deleted;
  int merged;
  int size;
  float diff;
};

void segment_calc(struct segment *s, const struct image *i) {
  float threshold = 0.1;
  for (int b = 0; b < SEGMENT_BUCKETS; ++b) {
```

```
    s->bucket[b] = 0;
  }
  int n = i->width * i->height;
  int m = n * 4;
  struct segment_edge *edges = malloc(m * sizeof(struct segment_edge));
  int e = 0;                                    //  ...
  for (int y = 0; y < i->height; ++y) {  //  .ox
  for (int x = 0; x < i->width; ++x) {   //  xxx
    edges[e].fx = x; edges[e].fy = y; edges[e].tx = (x + 1) % i->width; edges[e]
        ].ty = y; segment_weight(&edges[e], i); e++;
    edges[e].fx = x; edges[e].fy = y; edges[e].tx = x; edges[e].ty = (y + 1) % i
        ->height; segment_weight(&edges[e], i); e++;
    edges[e].fx = x; edges[e].fy = y; edges[e].tx = (x + 1) % i->width; edges[e]
        ].ty = (y + 1) % i->height; segment_weight(&edges[e], i); e++;
    edges[e].fx = x; edges[e].fy = y; edges[e].tx = (x - 1 + i->width) % i->
        width; edges[e].ty = (y + 1) % i->height; segment_weight(&edges[e], i)
        ; e++;
  }
  }
  qsort(edges, m, sizeof(struct segment_edge), segment_compare);
  struct image *S = image_alloc(i->width, i->height, 1);
  int k = 0;
  for (int y = 0; y < i->height; ++y) {
  for (int x = 0; x < i->width; ++x) {
    I(S,x,y,0) = k++;
  }
  }
  struct segment_component *components = malloc(n * sizeof(struct
      segment_component));
  for (k = 0; k < n; ++k) {
    components[k].deleted = 0;
    components[k].merged = -1;
    components[k].size = 1;
    components[k].diff = 0;
  }
  for (int q = 0; q < m; ++q) {
    int ci = I(S, edges[q].fx, edges[q].fy, 0);
    int cj = I(S, edges[q].tx, edges[q].ty, 0);
    while (components[ci].deleted) { ci = components[ci].merged; }
    while (components[cj].deleted) { cj = components[cj].merged; }
    if (ci != cj) {
      if (ci > cj) { int t = cj; cj = ci; ci = t; }
      float d = fminf(components[ci].diff + threshold / components[ci].size,
                      components[cj].diff + threshold / components[cj].size);
      if (edges[q].w <= d) {
        components[ci].size += components[cj].size;
        components[ci].diff = fmaxf(fmaxf(components[ci].diff, components[cj].
            diff), edges[q].w);
        components[cj].deleted = 1;
        components[cj].merged = ci;
        I(S, edges[q].fx, edges[q].fy, 0) = ci;
        I(S, edges[q].tx, edges[q].ty, 0) = ci;
      }
    }
  }
  image_free(S); S = NULL;
  free(edges); edges = NULL;
```

```
  for (int c = 0; c < n; ++c) {
    if (!components[c].deleted) {
      int b = logtwo(components[c].size);
      s->bucket[b] += components[c].size;
    }
  }
  free(components); components = NULL;
  for (int b = 0; b < SEGMENT_BUCKETS; ++b) {
    s->bucket[b] /= n;
  }
}
```

90 src/segment.h

```
/* ==========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------
CPU-Based Image Segmentation
========================================================================== */

#ifndef SEGMENT_H
#define SEGMENT_H 1

#include "image.h"

#define SEGMENT_BUCKETS 32
struct segment {
  float bucket[SEGMENT_BUCKETS];
};

void segment_calc(struct segment * s, const struct image *i);

#endif
```

91 src/sequence.c

```
/* ==========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010,2019  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------
Sequencer module
========================================================================== */

#include <math.h>
#include <GL/glew.h>
#include <GL/glut.h>
#include "sequence.h"
#include "sequence.vert.c"
#include "sequence.frag.c"
#if 0
struct sequence *sequence_init(struct sequence *sequence) {
  if (! shader_init(&sequence->shader, sequence_vert, sequence_frag)) {
    return 0;
  }
  shader_uniform(sequence, texture);
```

```
20    shader_uniform(sequence, pack);
      shader_uniform(sequence, size);
      glyphs_init(&sequence->glyphs);
      for (int i = 0; i < SEQUENCE_LENGTH; ++i) {
        sequence->seq1[i].active = 0;
25      sequence->seq1[i].index = -(i == 0);
        sequence->seq2[i].active = 0;
        sequence->seq2[i].index = -1;
        // pitch sequence
        sequence->pitch[i].active = 0;
30      sequence->pitch[i].pitch = 50;
      }
      sequence->page = seqpage_library;
      sequence->step = 0;
      sequence->cursor = 0;
35    sequence->frame = 0;
      return sequence;
    }

    void sequence_reshape(struct sequence *sequence, int w, int h) {
40    sequence->width = w;
      sequence->height = h;
    }

    void sequence_display(struct sequence *sequence, struct library *library, struct↙
        ↪ reactiondiffusion *react, struct audio *audio) {
45    glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);

      // reaction sequence
      if (sequence->seq1[sequence->step].active) {
        struct libelem *e = &library->array[sequence->seq1[sequence->step].index];
50      react->value.ru = e->v[0];
        react->value.rv = e->v[1];
        react->value.f  = e->v[2];
        react->value.k  = e->v[3];
      }
55
      // pitch sequence
      if (sequence->pitch[sequence->step].active) {
        audio->pitch = sequence->pitch[sequence->step].pitch;
      }
60
    #if 0
      // curve/speed sequence
      if (sequence->frame == 0 && sequence->seq2[sequence->step].active) {
        switch (sequence->seq2[sequence->step].index) {
65      case sequence_curve_less: audio->dcurve = fmax(audio->dcurve - 1.0, -1.0); ↙
            ↪ break;
        case sequence_curve_more: audio->dcurve = fmin(audio->dcurve + 1.0,  1.0); ↙
            ↪ break;
        case sequence_speed_less: audio->dspeed = fmax(audio->dspeed - 1.0, -1.0); ↙
            ↪ break;
        case sequence_speed_more: audio->dspeed = fmin(audio->dspeed + 1.0,  1.0); ↙
            ↪ break;
        default: break;
70      }
      }
```

```
    if (sequence->frame == 0) {
      audio->speed += audio->dspeed;
      audio->curve += audio->dcurve;
    }
#endif

    glMatrixMode(GL_PROJECTION);
    glLoadIdentity();
    glViewport(0, 0, sequence->width, sequence->height);
    gluOrtho2D(0, sequence->width, 0, sequence->height);
    glMatrixMode(GL_MODELVIEW);
    glLoadIdentity();

    // sequence 1: library balls
    glEnable(GL_TEXTURE_2D);
    glBindTexture(GL_TEXTURE_2D, library->tex[library->which]);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
    glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
    glUseProgramObjectARB(sequence->shader.program);
    sequence->attr.spin   = glGetAttribLocationARB(sequence->shader.program, "↙
        ↪ myspin0");
//  sequence->attr.step   = glGetAttribLocationARB(sequence->shader.program, "↙
    ↪ mystep0");
    sequence->attr.cursor = glGetAttribLocationARB(sequence->shader.program, "↙
        ↪ mycursor0");
    sequence->attr.active = glGetAttribLocationARB(sequence->shader.program, "↙
        ↪ myactive0");
    sequence->attr.pitch  = glGetAttribLocationARB(sequence->shader.program, "↙
        ↪ mypitch0");
    sequence->value.texture = 0;
    sequence->value.pack    = library_pack;
    sequence->value.size    = library_packed_size;
    shader_updatei(sequence, texture);
    shader_updatef(sequence, pack);
    shader_updatef(sequence, size);
    glBegin(GL_QUADS); {
      for (int j = 0; j < SEQUENCE_LENGTH; ++j) {
        float t = sequence->step + sequence->frame / 12.0;
        float x0 = library->width * (j + 0.5) / SEQUENCE_LENGTH;
        float y0 = library->width * 0.5 / SEQUENCE_LENGTH;
        float d = 1.0 / (0.3 + pow(fmin(fmin(fabs(t - j), fabs(t - j + ↙
            ↪ SEQUENCE_LENGTH)), fabs(t - j - SEQUENCE_LENGTH))/(SEQUENCE_LENGTH↙
            ↪ /2.0), 0.5));
        float dx = (0.75 + 0.25 * d) * y0;
        float dy = (0.75 + 0.25 * d) * y0;
          int i = sequence->seq1[j].index;
//          glVertexAttrib1f(sequence->attr.step,   j == sequence->step);
          glVertexAttrib1f(sequence->attr.cursor, j == sequence->cursor);
          glVertexAttrib1f(sequence->attr.active, sequence->seq1[j].active);
          glVertexAttrib1f(sequence->attr.pitch,  sequence->pitch[j].active ? ↙
              ↪ sequence->pitch[j].pitch / 5 : 0);
        if (sequence->seq1[j].active) {
          glVertexAttrib2f(sequence->attr.spin, library->array[i].spin[0], library↙
              ↪ ->array[i].spin[1]);
          glTexCoord4f( (i % library_pack)       / (float) library_pack, ((i / ↙
              ↪ library_pack) + 1) / (float) library_pack, 0, 1);
        } else {
```

```
          glVertexAttrib2f(sequence->attr.spin, 0, 0);
120       glTexCoord4f(-1,-1,0,1);
        }
          glVertex2f(x0 - dx, y0 + dy);
//        glVertexAttrib1f(sequence->attr.step,   j == sequence->step);
          glVertexAttrib1f(sequence->attr.cursor, j == sequence->cursor);
125       glVertexAttrib1f(sequence->attr.active, sequence->seq1[j].active);
          glVertexAttrib1f(sequence->attr.pitch,  sequence->pitch[j].active ? ↙
              ↳ sequence->pitch[j].pitch / 5 : 0);
        if (sequence->seq1[j].active) {
          glVertexAttrib2f(sequence->attr.spin, library->array[i].spin[0], library↙
              ↳ ->array[i].spin[1]);
          glTexCoord4f(((i % library_pack) + 1) / (float) library_pack, ((i / ↙
              ↳ library_pack) + 1) / (float) library_pack, 1, 1);
130       } else {
          glVertexAttrib2f(sequence->attr.spin, 0, 0);
          glTexCoord4f(-1,-1,1,1);
        }
          glVertex2f(x0 + dx, y0 + dy);
135 //        glVertexAttrib1f(sequence->attr.step,   j == sequence->step);
          glVertexAttrib1f(sequence->attr.cursor, j == sequence->cursor);
          glVertexAttrib1f(sequence->attr.active, sequence->seq1[j].active);
          glVertexAttrib1f(sequence->attr.pitch,  sequence->pitch[j].active ? ↙
              ↳ sequence->pitch[j].pitch / 5 : 0);
        if (sequence->seq1[j].active) {
140       glVertexAttrib2f(sequence->attr.spin, library->array[i].spin[0], library↙
              ↳ ->array[i].spin[1]);
          glTexCoord4f(((i % library_pack) + 1) / (float) library_pack,  (i / ↙
              ↳ library_pack)      / (float) library_pack, 1, 0);
        } else {
          glVertexAttrib2f(sequence->attr.spin, 0, 0);
          glTexCoord4f(-1,-1,1,0);
145     }
          glVertex2f(x0 + dx, y0 - dy);
//        glVertexAttrib1f(sequence->attr.step,   j == sequence->step);
          glVertexAttrib1f(sequence->attr.cursor, j == sequence->cursor);
          glVertexAttrib1f(sequence->attr.active, sequence->seq1[j].active);
150       glVertexAttrib1f(sequence->attr.pitch,  sequence->pitch[j].active ? ↙
              ↳ sequence->pitch[j].pitch / 5 : 0);
        if (sequence->seq1[j].active) {
          glVertexAttrib2f(sequence->attr.spin, library->array[i].spin[0], library↙
              ↳ ->array[i].spin[1]);
          glTexCoord4f( (i % library_pack)      / (float) library_pack,  (i / ↙
              ↳ library_pack)      / (float) library_pack, 0, 0);
        } else {
155       glVertexAttrib2f(sequence->attr.spin, 0, 0);
          glTexCoord4f(-1,-1,0,0);
        }
          glVertex2f(x0 - dx, y0 - dy);
      }
160   } glEnd();
      glUseProgramObjectARB(0);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
      glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_NEAREST);

165 #if 0
      // sequence 2: speed/curve controls
```

```
  glEnable(GL_BLEND);
  glBlendFunc(GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA);
  for (int j = 0; j < SEQUENCE_LENGTH; ++j) {
    if (sequence->seq2[j].active) {
      glBindTexture(GL_TEXTURE_2D, sequence->glyphs.textures[sequence->seq2[j].index]);
      glBegin(GL_QUADS); {
        float t = sequence->step + sequence->frame / 12.0;
        float x0 = library->width * (j + 0.5) / SEQUENCE_LENGTH;
        float y0 = 32;
        float d = 1.0 / (0.3 + pow(fmin(fmin(fabs(t - j), fabs(t - j + SEQUENCE_LENGTH)), fabs(t - j - SEQUENCE_LENGTH))/(SEQUENCE_LENGTH/2.0), 0.5));
        float dx = 24 + 8 * d;
        float dy = 24 + 8 * d;
        glColor4f(1,1,1,1);
        glTexCoord2f(0, 0); glVertex2f(x0 + dx, y0 + dy);
        glTexCoord2f(0, 1); glVertex2f(x0 + dx, y0 - dy);
        glTexCoord2f(1, 1); glVertex2f(x0 - dx, y0 - dy);
        glTexCoord2f(1, 0); glVertex2f(x0 - dx, y0 + dy);
      } glEnd();
    }
  }
  glDisable(GL_BLEND);
#endif

  glBindTexture(GL_TEXTURE_2D, 0);
  glDisable(GL_TEXTURE_2D);
  if (++sequence->frame == 12) {
    sequence->frame = 0;
    if (++sequence->step == SEQUENCE_LENGTH) {
      sequence->step = 0;
    }
  }

}

int sequence_keynormal(struct sequence *sequence, struct library *library, int key, int x, int y) {
  switch (key) {
/*
    case '[':
      switch (sequence->page) {
        case seqpage_curves:
          sequence->seq2[sequence->cursor].index = sequence_curve_less;
          sequence->seq2[sequence->cursor].active = 1;
          return 1;
        default:
          return 0;
      }
    case ']':
      switch (sequence->page) {
        case seqpage_curves:
          sequence->seq2[sequence->cursor].index = sequence_curve_more;
          sequence->seq2[sequence->cursor].active = 1;
          return 1;
        default:
```

```
220             return 0;
        }
*/
      case ' ':
        switch (sequence->page) {
225       case seqpage_library:
            sequence->seq1[sequence->cursor].active = 0;
            sequence->seq1[sequence->cursor].index = -1;
            return 1;
          case seqpage_curves:
230         sequence->seq2[sequence->cursor].active = 0;
            sequence->seq2[sequence->cursor].index = -1;
            return 1;
        }

235     // pitch sequence
#define P(c,p) \
      case c: sequence->pitch[sequence->cursor].pitch = p; sequence->pitch[↙
          ↳ sequence->cursor].active = 1; return 1
        P('7', 80); P('8', 85); P('9', 90); P('0', 95); P('-', 100);
        P('u', 60); P('i', 65); P('o', 70); P('p', 75);
240     P('j', 40); P('k', 45); P('l', 50); P(';', 55);
        P('m', 20); P(',', 25); P('.', 30); P('/', 35);
#undef P
      case 'n': sequence->pitch[sequence->cursor].active = 0; return 1;

245     default:
        return 0;
    }
}

250 int sequence_keyspecial(struct sequence *sequence, struct library *library, int ↙
      ↳ key, int x, int y) {
    switch (key) {
      case GLUT_KEY_LEFT:
        sequence->cursor = (sequence->cursor + SEQUENCE_LENGTH - 1) % ↙
            ↳ SEQUENCE_LENGTH;
        return 1;
255   case GLUT_KEY_RIGHT:
        sequence->cursor = (sequence->cursor + 1) % SEQUENCE_LENGTH;
        return 1;
      case GLUT_KEY_UP:
        switch (sequence->page) {
260     case seqpage_library:
          sequence->seq1[sequence->cursor].index = rand() % library->count;
          sequence->seq1[sequence->cursor].active = 1;
          break;
        case seqpage_curves:
265       sequence->seq2[sequence->cursor].index = sequence_speed_more;
          sequence->seq2[sequence->cursor].active = 1;
          break;
        }
        return 1;
270   case GLUT_KEY_DOWN:
        switch (sequence->page) {
        case seqpage_library:
          sequence->seq1[sequence->cursor].active = 0;
```

```
        sequence->seq1[sequence->cursor].index = -1;
        break;
      case seqpage_curves:
        sequence->seq2[sequence->cursor].index = sequence_speed_less;
        sequence->seq2[sequence->cursor].active = 1;
        break;
      }
      return 1;
    case GLUT_KEY_PAGE_UP:
      sequence->page = seqpage_library;
      return 1;
    case GLUT_KEY_PAGE_DOWN:
      sequence->page = seqpage_curves;
      return 1;
    default:
      return 0;
  }
}
#endif
```

92 src/sequence.frag

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Sphere shader for sequencer
================================================================ */

uniform sampler2D texture;
uniform float pack;
uniform float size;

varying vec2 myspin2;
varying float mycursor2;
//varying float mystep2;
varying float myactive2;
varying float mypitch2;

void main(void) {
  vec2 p = gl_TexCoord[0].xy;                // float in [0..1]
  vec2 q0 = gl_TexCoord[0].zw;
  vec2 q1 = 3.0 * (q0 - vec2(0.5, 0.5));
  float d = dot(q1,q1);
  if (d < 1.0 && 0.0 < myactive2) {
    vec3 n = normalize(vec3(q1, sqrt(1.0-d)));
    vec2 q = q1 / (1.0 + sqrt(1.0 - d));
    vec2 q2 = 0.5 * q + myspin2;
    vec2 cell = floor(p * pack);             // int   in [0..(pack-1)]
    //vec2 frac = p * pack - cell;             // float in [0..1]
    //vec2 frac = vec2(0.0, 0.0);
    vec2 frac = q2;
    frac -= floor(frac);
    // FIXME check the ratio - maybe (size/pack) / (size/pack + 2) instead?
    frac -= vec2(0.5, 0.5);
    frac *= (size / pack - 2.0) / (size / pack);
    frac += vec2(0.5, 0.5);
```

```
      vec2 px0 = floor(  frac * size / pack ); // pixels
      vec2 px1 = px0 + vec2(1.0, 1.0);          // pixels
      // coordinates to interpolate
      vec2 p0 = cell / pack + px0 / size;
      vec2 p1 = cell / pack + px1 / size;
      vec2 dp = frac;
      // linear interpolation
      vec3 tl = texture2D(texture, p0).rgb;
      vec3 tr = texture2D(texture, vec2(p1.x, p0.y)).rgb;
      vec3 bl = texture2D(texture, vec2(p0.x, p1.y)).rgb;
      vec3 br = texture2D(texture, p1).rgb;
      vec3 t = tl * (1.0 - dp.x) + dp.x * tr;
      vec3 b = bl * (1.0 - dp.x) + dp.x * br;
      vec3 l = tl * (1.0 - dp.y) + dp.y * bl;
      vec3 r = tr * (1.0 - dp.y) + dp.y * br;
      vec3 m1 = t * (1.0 - dp.y) + dp.y * b;
      vec3 m2 = l * (1.0 - dp.x) + dp.x * r;
      vec3 m = 0.5 * (m1 + m2);
      // output
      float a = 1.0;
      float k = gl_FragCoord.z - 0.1 * cos(sqrt(d) * 3.1415926*0.5);
      float c = 0.0625 + pow(dot(vec3(0.0, 0.0, 1.0), n), 2.0);
      gl_FragDepth = k;
      gl_FragColor = vec4(m * c, a);
    } else if (abs(d - 1.3) < 0.3 && 0.0 < mycursor2) {
      float c = 1.0 - abs(d - 1.3) / 0.3;
      float a = fract((atan(q1.y, q1.x) / (3.1415926 * 2.0) + 0.5) * mypitch2) < ↙
          ↳ 0.5 ? 1.0 : 0.0;
      gl_FragDepth = gl_FragCoord.z;
      gl_FragColor = vec4(0.0, a * c*c, 0.0, c*c);
    } else {
      discard;
    }
  }
```

93 src/sequence.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Sequencer module
============================================================================ */

#ifndef SEQUENCE_H
#define SEQUENCE_H 1

#include "shader.h"
#include "library.h"
#include "reactiondiffusion.h"
#include "audio.h"
#include "glyphs.h"

#define SEQUENCE_LENGTH 16

struct seqelem {
  int active; // is this step going to change things
```

```
  int index;  // index for this step
};

enum sequence_page { seqpage_library, seqpage_curves };

struct sequence { struct shader shader;
  struct {
    GLint texture, pack, size; // fragment
  } uniform;
  struct {
    int texture; float pack, size; // fragment
  } value;
  struct {
    GLint spin, cursor, step, active, pitch; // vertex
  } attr;
  struct seqelem seq1[SEQUENCE_LENGTH]; // library index

  struct { int active; float pitch; } pitch[SEQUENCE_LENGTH]; // pitch sequence

  struct glyphs glyphs;
  struct seqelem seq2[SEQUENCE_LENGTH]; // curve/speed controls
  enum sequence_page page;
  int step;
  int cursor;
  int frame;
  int width;
  int height;
};

struct sequence *sequence_init(struct sequence *sequence);
void sequence_reshape(struct sequence *sequence, int w, int h);
void sequence_display(struct sequence *sequence, struct library *library, struct reactiondiffusion *react, struct audio *audio);
int sequence_keynormal(struct sequence *sequence, struct library *library, int key, int x, int y);
int sequence_keyspecial(struct sequence *sequence, struct library *library, int key, int x, int y);

#endif
```

94 src/sequence.vert

```
/* ==========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
--------------------------------------------------------------------------
Sequence vertex shader
========================================================================== */

attribute vec2 myspin0;
//attribute float mystep0;
attribute float mycursor0;
attribute float myactive0;
attribute float mypitch0;

varying vec2 myspin2;
//varying float mystep2;
```

```
varying float mycursor2;
varying float myactive2;
varying float mypitch2;

void main(void) {
  gl_TexCoord[0] = gl_MultiTexCoord0;
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
  myspin2 = myspin0;
//  mystep2 = mystep0;
  mycursor2 = mycursor0;
  myactive2 = myactive0;
  mypitch2 = mypitch0;
}
```

95 src/shader.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Generic Shader
================================================================ */

#include <stdio.h>
#include <stdlib.h>
#include "shader.h"

//================================================================
// print a shader object's debug log
void shader_debug(GLhandleARB obj) {
//  return; // FIXME: only dump logs when shader compile/link failed
  int infologLength = 0;
  int maxLength;
  if (glIsShader(obj)) {
    glGetShaderiv(obj, GL_INFO_LOG_LENGTH, &maxLength);
  } else {
    glGetProgramiv(obj, GL_INFO_LOG_LENGTH, &maxLength);
  }
  char *infoLog = malloc(maxLength);
  if (!infoLog) {
    return;
  }
  if (glIsShader(obj)) {
    glGetShaderInfoLog(obj, maxLength, &infologLength, infoLog);
  } else {
    glGetProgramInfoLog(obj, maxLength, &infologLength, infoLog);
  }
  if (infologLength > 0) {
    fprintf(stderr, "%s\n", infoLog);
  }
  free(infoLog);
}

//================================================================
// generic shader uniform location access macro
#define shader_uniform(self,name) \
  (self)->uniform.name = \
```

```
    glGetUniformLocationARB((self)->shader.program, #name)

//============================================================================
// generic shader uniform update access macro (integer)
#define shader_updatei(self,name) \
  glUniform1iARB((self)->uniform.name, (self)->value.name)

//============================================================================
// generic shader uniform update access macro (float)
#define shader_updatef(self,name) \
  glUniform1fARB((self)->uniform.name, (self)->value.name)

//============================================================================
// generic shader initialization
struct shader *shader_init(
  struct shader *shader, const char *vert, const char *frag
) {
  if (!shader) { return 0; }
  shader->linkStatus     = 0;
  shader->vertexSource   = vert;
  shader->fragmentSource = frag;
  if (shader->vertexSource || shader->fragmentSource) {
    shader->program = glCreateProgramObjectARB();
    if (shader->vertexSource) {
      shader->vertex =
        glCreateShaderObjectARB(GL_VERTEX_SHADER_ARB);
      glShaderSourceARB(shader->vertex,
        1, (const GLcharARB **) &shader->vertexSource, 0
      );
      glCompileShaderARB(shader->vertex);
      shader_debug(shader->vertex);
      glAttachObjectARB(shader->program, shader->vertex);
    }
    if (shader->fragmentSource) {
      shader->fragment =
        glCreateShaderObjectARB(GL_FRAGMENT_SHADER_ARB);
      glShaderSourceARB(shader->fragment,
        1, (const GLcharARB **) &shader->fragmentSource, 0
      );
      glCompileShaderARB(shader->fragment);
      shader_debug(shader->fragment);
      glAttachObjectARB(shader->program, shader->fragment);
    }
    glLinkProgramARB(shader->program);
    shader_debug(shader->program);
    glGetObjectParameterivARB(shader->program,
      GL_OBJECT_LINK_STATUS_ARB, &shader->linkStatus
    );
    if (!shader->linkStatus) { return 0; }
  } else { return 0; }
  return shader;
}
```

96 src/shader.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
```

```
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
-------------------------------------------------------------------------
Generic Shader
=========================================================================*/

#ifndef SHADER_H
#define SHADER_H 1

#include <GL/glew.h>

//=========================================================================
// generic shader data
struct shader {
  GLint linkStatus;
  GLhandleARB program;
  GLhandleARB fragment;
  GLhandleARB vertex;
  const GLcharARB *fragmentSource;
  const GLcharARB *vertexSource;
};

//=========================================================================
// generic shader uniform location access macro
#define shader_uniform(self,name) \
  (self)->uniform.name = \
    glGetUniformLocationARB((self)->shader.program, #name)

//=========================================================================
// generic shader uniform update access macro (integer)
#define shader_updatei(self,name) \
  glUniform1iARB((self)->uniform.name, (self)->value.name)

//=========================================================================
// generic shader uniform update access macro (float)
#define shader_updatef(self,name) \
  glUniform1fARB((self)->uniform.name, (self)->value.name)

//=========================================================================
// generic shader uniform update access macro (float2)
#define shader_updatef2(self,name) \
  glUniform2fARB((self)->uniform.name, (self)->value.name[0], (self)->value.name
    ↳ [1])

//=========================================================================
// generic shader uniform update access macro (float4)
#define shader_updatef4(self,name) \
  glUniform4fARB((self)->uniform.name, (self)->value.name[0], (self)->value.name
    ↳ [1], (self)->value.name[2], (self)->value.name[3])

//=========================================================================
// generic shader uniform update access macro (matrix4)
#define shader_updatem4(self,name) \
  glUniformMatrix4fvARB((self)->uniform.name, 1, 0, &((self)->value.name[0]))

//=========================================================================
// generic shader initialization
struct shader *shader_init(
```

```
  struct shader *shader, const char *vert, const char *frag
);

#endif
```

97 src/svg2o.sh

```
#!/bin/bash
SVGFILE="${1}.svg"
PNGFILE="${1}.png"
PPMFILE="${1}.ppm"
PGMFILE="${1}.pgm"
RGBFILE="${1}.rgb"
AFILE="${1}.a"
RGBAFILE="${1}.rgba"
OFILE="${1}.o"
rsvg-convert "${SVGFILE}" > "${PNGFILE}"
pngtopnm          "${PNGFILE}" > "${PPMFILE}"
pngtopnm -alpha "${PNGFILE}" > "${PGMFILE}"
tail -c 49152 "${PPMFILE}" > "${RGBFILE}"
tail -c 16384 "${PGMFILE}" > "${AFILE}"
./interleave31 "${RGBFILE}" "${AFILE}" 128 > "${RGBAFILE}"
#objcopy --input binary --output elf32-i386 --binary-architecture i386 "${
    ↪ RGBAFILE}" "${OFILE}"
objcopy --input binary --output elf64-x86-64 --binary-architecture i386 "${
    ↪ RGBAFILE}" "${OFILE}"
rm -f "${PNGFILE}" "${PPMFILE}" "${PGMFILE}" "${RGBFILE}" "${AFILE}" "${RGBAFILE
    ↪ }"
```

98 src/tamura.c

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2017 Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
Based on: fire-2.2/FeatureExtractors/tamurafeature.cpp
Homepage: http://www-i6.informatik.rwth-aachen.de/~deselaers/fire/
----------------------------------------------------------------------------
Tumara Feature Extraction
============================================================================ */

#define _DEFAULT_SOURCE 1

#include <assert.h>
#include <math.h>
#include "tamura.h"

float tamura_coarseness(
  struct tamura *tamura, struct image *image, int channel
);
float tamura_directionality(
  struct tamura *tamura, struct image *image, int channel
);
float tamura_contrast(
  struct tamura *tamura, struct image *image, int channel
);
```

```
float tamura_localmean(struct tamura *tamura, int x, int y, int k);
void tamura_runningsum(
  struct tamura *tamura, struct image *image, int channel
);

struct tamura *tamura_init(
  struct tamura *tamura, int width, int height
) {
  assert(tamura);
  assert(width > 0);
  assert(height > 0);
  tamura->width    = width;
  tamura->height   = height;
  tamura->Rsum  = image_alloc(width, height, 1);  assert(tamura->Rsum);
  tamura->Ak    = image_alloc(width, height, 5);  assert(tamura->Ak);
  tamura->Ekh   = image_alloc(width, height, 5);  assert(tamura->Ekh);
  tamura->Ekv   = image_alloc(width, height, 5);  assert(tamura->Ekv);
  tamura->Sbest = image_alloc(width, height, 1);  assert(tamura->Sbest);
  return tamura;
}

void tamura_calculate(
  struct tamura *tamura,
  struct tamura_features *features,
  struct image *image
) {
  assert(tamura);
  assert(features);
  assert(image);
  assert(tamura->width  == image->width);
  assert(tamura->height == image->height);
  assert(2              <= image->channels);
  for (int c = 0; c < 2; ++c) {
    features[c].coarseness     = tamura_coarseness    (tamura, image, c);
    features[c].contrast       = tamura_contrast      (tamura, image, c);
    features[c].directionality = tamura_directionality(tamura, image, c);
  }
}

void tamura_runningsum(
  struct tamura *tamura, struct image *image, int channel
) {
  struct image *r = tamura->Rsum;
  float l, u, ul;
  for (int y = 0; y < tamura->height; ++y) {
    for (int x = 0; x < tamura->width; ++x) {
      l  = x      ? I(r,x-1,y,  0) : 0;
      u  = y      ? I(r,x,  y-1,0) : 0;
      ul = x && y ? I(r,x-1,y-1,0) : 0;
      I(r,x,y,0) = I(image,x,y,channel) + l + u + ul;
    }
  }
}

float tamura_localmean(struct tamura *tamura, int x, int y, int k) { // FIXME ↙
    ↳ handle wrap-around more excitingly
  struct image *r = tamura->Rsum;
```

```
  int k2 = k/2;
  int x0 = x - k2 - 1;
  int x1 = x + k2 - 1;
  int y0 = y - k2 - 1;
  int y1 = y + k2 - 1;
  if (x0 < 0) x0 = 0;
  if (y0 < 0) y0 = 0;
  if (x1 >= tamura->width ) x1 = tamura->width  - 1;
  if (y1 >= tamura->height) y1 = tamura->height - 1;
  int count = (x1 - x0 + 1) * (y1 - y0 + 1);
  float l  = x0 > 0           ? I(r,x0-1,y1,  0) : 0;
  float t  = y0 > 0           ? I(r,x1,  y0-1,0) : 0;
  float tl = x0 > 0 && y0 > 0 ? I(r,x0-1,y0-1,0) : 0;
  float b  =                    I(r,x1,  y1,  0);
  return (b - l - t + tl) / count;
}

float tamura_contrast(
  struct tamura *tamura, struct image *image, int channel
) {
  float size = 121.0;
  float contrast = 0;
  for (int y = 0; y < tamura->height; ++y) {
    for (int x = 0; x < tamura->width; ++x) {
      float mean = 0;
      float sigma = 0;
      float kurtosis = 0;
      for (int j = y - 5; j <= y + 5; ++j) {
        int jj = j;
        while (jj <  0             ) { jj += tamura->height; }
        while (jj >= tamura->height) { jj -= tamura->height; }
        for (int i = x - 5; i <= x + 5; ++i) {
          int ii = i;
          while (ii <  0            ) { ii += tamura->width; }
          while (ii >= tamura->width) { ii -= tamura->width; }
          float t = I(image,ii,jj,channel);
          mean += t;
          sigma += t*t;
        }
      }
      mean /= size;
      sigma /= size;
      sigma -= mean * mean;
      for (int j = y - 5; j <= y + 5; ++j) {
        int jj = j;
        while (jj <  0             ) { jj += tamura->height; }
        while (jj >= tamura->height) { jj -= tamura->height; }
        for (int i = x - 5; i <= x + 5; ++i) {
          int ii = i;
          while (ii <  0            ) { ii += tamura->width; }
          while (ii >= tamura->width) { ii -= tamura->width; }
          float t = I(image,ii,jj,channel) - mean;
          t *= t;
          t *= t;
          kurtosis += t;
        }
      }
```

```
      kurtosis /= size;
      if (kurtosis > 0.000001) {
        contrast += sigma / sqrtf(sqrtf(kurtosis));
      }
    }
  }
  return contrast / (tamura->width * tamura->height);
}

float tamura_directionality(
  struct tamura *tamura, struct image *image, int channel
) {
  const float mh[3][3] = { { 1, 2, 1 }, { 0, 0, 0 }, { -1, -2, -1 } };
  const float mv[3][3] = { { 1, 0, -1 }, { 2, 0, -2 }, { 1, 0, -1 } };
  float phi = 0;
  for (int y = 0; y < tamura->height; ++y) {
    for (int x = 0; x < tamura->width; ++x) {
      float v = 0, h = 0;
      for (int j = 0; j < 3; ++j) {
        int jj = y + j - 1;
        while (jj <  0             ) { jj += tamura->height; }
        while (jj >= tamura->height) { jj -= tamura->height; }
        for (int i = 0; i < 3; ++i) {
          int ii = x + i - 1;
          while (ii <  0            ) { ii += tamura->width; }
          while (ii >= tamura->width) { ii -= tamura->width; }
          float t = I(image,ii,jj,channel);
          h += mh[i][j] * t;
          v += mv[i][j] * t;
        }
      }
      phi += sqrtf(0.5f*(h*h+v*v));
      //if (h != 0) { phi += atanf(v/h) + M_PI/2.0 + 0.001; } // FIXME ?
    }
  }
  return phi / (tamura->width * tamura->height);
}

float tamura_coarseness(
  struct tamura *tamura, struct image *image, int channel
) {
  tamura_runningsum(tamura, image, channel);
  //step 1
  int lenOfk=1;
  for(int k=1;k<=5;++k) {
    lenOfk*=2;
    for(int y=0;y<tamura->height;++y) {
      for(int x=0;x<tamura->width;++x) {
        I(tamura->Ak,x,y,k-1) = tamura_localmean(tamura,x,y,lenOfk);
      }
    }
  }
  //step 2
  lenOfk=1;
  for(int k=1;k<=5;++k) {
    int k2=lenOfk;
    lenOfk*=2;
```

```
    for(int y=0;y<tamura->height;++y) {
      for(int x=0;x<tamura->width;++x) {
        int posx1=x+k2;
        int posx2=x-k2;
        int posy1=y+k2;
        int posy2=y-k2;
        if(posx1<tamura->width && posx2>=0) {
          I(tamura->Ekh,x,y,k-1)=fabsf(I(tamura->Ak,posx1,y,k-1)-I(tamura->Ak,
              posx2,y,k-1));
        } else {
          I(tamura->Ekh,x,y,k-1)=0;
        }
        if(posy1<tamura->height && posy2>=0) {
          I(tamura->Ekv,x,y,k-1)=fabsf(I(tamura->Ak,x,posy1,k-1)-I(tamura->Ak,x,
              posy2,k-1));
        } else {
          I(tamura->Ekv,x,y,k-1)=0;
        }
      }
    }
  }
  float coarseness=0.0;
  //step3
  for(int y=0;y<tamura->height;++y) {
    for(int x=0;x<tamura->width;++x) {
      float maxE=0;
      int maxk=0;
      for(int k=1;k<=5;++k) {
        if(I(tamura->Ekh,x,y,k-1)>maxE) {
          maxE=I(tamura->Ekh,x,y,k-1);
          maxk=k;
        }
        if(I(tamura->Ekv,x,y,k-1)>maxE) {
          maxE=I(tamura->Ekv,x,y,k-1);
          maxk=k;
        }
      }
//      I(tamura->Sbest,x,y,0)=maxk;
      coarseness+=maxk;
    }
  }
  return coarseness / ((tamura->width - 32) * (tamura->height - 32));
}

/*
vector<uint> histogramImageBinImage(const ImageFeature &image) {
  vector<uint> result(image.xsize()*image.ysize());
  vector<double> t(3,0);

  vector<uint> steps(3,8);
  HistogramFeature tmp(steps);
  tmp.min()[0]=0;    tmp.max()[0]=1.0;
  tmp.min()[1]=0;    tmp.max()[1]=1.0;
  tmp.min()[2]=0;    tmp.max()[2]=1.0;

  tmp.initStepsize();

```

```
  for(uint x=0;x<image.xsize();++x) {
    for(uint y=0;y<image.ysize();++y) {
      for(uint z=0;z<3;++z) {t[z]=image(x,y,z);}
      result[y*image.xsize()+x]=tmp.posToBin(tmp.pointToPos(t));
    }
  }

  return result;
}

HistogramFeature histogramize(const ImageFeature image,
                              const vector<uint> &bins,
                              const uint left,
                              const uint top,
                              const uint right,
                              const uint bottom) {
  vector<uint> steps(3,8);
  HistogramFeature result(steps);
  result.min()[0]=0;    result.max()[0]=1.0;
  result.min()[1]=0;    result.max()[1]=1.0;
  result.min()[2]=0;    result.max()[2]=1.0;
  result.initStepsize();

  uint xsize=image.xsize();

  for(uint x=left;x<right;++x) {
    for(uint y=top;y<bottom;++y) {
      //      DBG(10) << y << " " << x << " "<< y*xsize+x << " " << bins[y*xsize+x] << endl;
      result.feedbin(bins[y*xsize+x]);
    }
  }

  return result;
}


HistogramFeature histogramize(const ImageFeature &image) {
  // min -> max: 0,0,0 -> pi,5,128
  // steps: 8,8,8

  vector<uint> steps(3,8);
  HistogramFeature result(steps);
  result.min()[0]=0;    result.max()[0]=1.0;
  result.min()[1]=0;    result.max()[1]=1.0;
  result.min()[2]=0;    result.max()[2]=1.0;
  result.initStepsize();

  vector<double> tmp(3,0.0);

  for(uint x=0;x<image.xsize();++x) {
    for(uint y=0;y<image.ysize();++y) {
      for(uint z=0;z<3;++z) {tmp[z]=image(x,y,z);}
      result.feed(tmp);
    }
  }
```

```
  return result;
}
*/
```

99 src/tamura.h

```
/* ========================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
------------------------------------------------------------------------
Based on: fire-2.2/FeatureExtractors/tamurafeature.cpp
Homepage: http://www-i6.informatik.rwth-aachen.de/~deselaers/fire/
------------------------------------------------------------------------
Tumara Feature Extraction
======================================================================== */

#ifndef TAMURA_H
#define TAMURA_H

#include "image.h"

struct tamura_features {
  float coarseness;
  float contrast;
  float directionality;
};

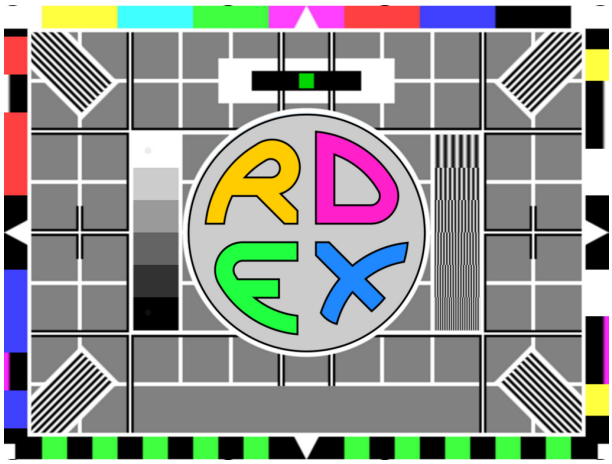
struct tamura {
  int width;
  int height;
  struct image *Rsum;  // w*h*1
  struct image *Ak;    // w*h*5
  struct image *Ekh;   // w*h*5
  struct image *Ekv;   // w*h*5
  struct image *Sbest; // w*h*1
};

struct tamura *tamura_init(
  struct tamura *tamura, int width, int height
);

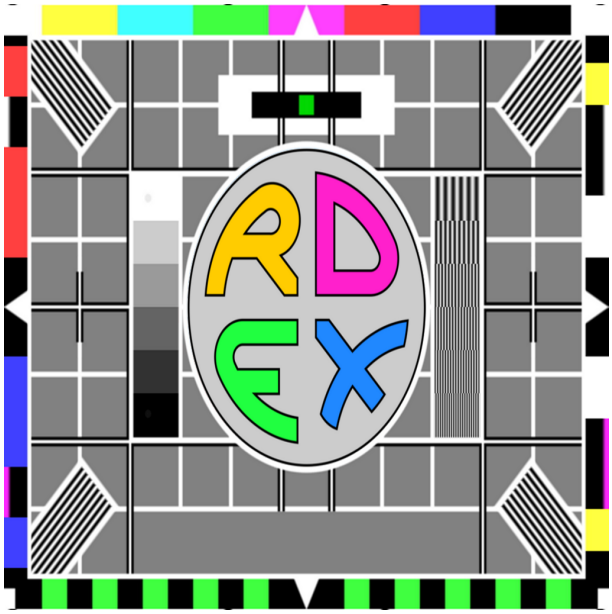
void tamura_calculate(
  struct tamura *tamura,
  struct tamura_features *features,
  struct image *image
);

#endif
```

100 src/test-card-intro.png



101 src/test-card-intro.ppm



102 src/test_gl.sh

```
#!/bin/bash
grep -h gl *.c | sed "s|.*gl\(.*\)(.*|gl\1|g" | grep -v "=" | grep -v "^#" |
grep -v "^/" | sed "s|(.*||g" | grep -v "^gls_" | grep -v "^global_" |
grep -v "^glXGetCurrent" | grep -v " " | sort | uniq |
(echo "
#include <stdio.h>
#include <stdlib.h>
#include <GL/glew.h>
#include <GL/glut.h>
static void test_display(void);
```

```
int main(int argc, char **argv) {
  glutInit(&argc, argv);
  glutInitDisplayMode(GLUT_RGBA | GLUT_DOUBLE | GLUT_DEPTH);
  glutInitWindowSize(640, 480);
  glutCreateWindow(\"test_gl\");
  glewInit();
  glutDisplayFunc(test_display);
  glutMainLoop();
  return 0;
}
static void test_display(void) {
" &&
 cat | sed 's|\(.*\)|printf("\1\\t\\t\\t%p\\n", \1);|g' && echo "
  exit(0);
}
") | gcc -xc - -o test_gl -lGLEW -lGL -lGLU -lglut && ./test_gl | grep "(nil)"
```

103 src/text.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Text module
================================================================ */

#include <math.h>
#include <GL/glew.h>
#include <GL/glut.h>
#include "text.h"
#include "text.vert.c"
#include "text.frag.c"

struct text *text_init(struct text *text) {
  if (! shader_init(&text->shader, text_vert, text_frag)) {
    return 0;
  }
  shader_uniform(text, texture);
  fonts_init(&text->fonts);
  for (int i = 0; i < TEXT_LENGTH; ++i) {
    text->textstr[i] = ' ';
  }
  return text;
}

void text_reshape(struct text *text, int w, int h) {
  text->width = w;
  text->height = h;
}

void text_display(struct text *text) {
  glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);

  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  glViewport(0, 0, text->width, text->height);
  gluOrtho2D(0, text->width, 0, text->height);
```

```
  glMatrixMode(GL_MODELVIEW);
  glLoadIdentity();

  // text
  glEnable(GL_TEXTURE_2D);
  glBindTexture(GL_TEXTURE_2D, text->fonts.texture);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);
  glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
  glUseProgramObjectARB(text->shader.program);
  text->value.texture = 0;
  shader_updatei(text, texture);
  glBegin(GL_QUADS); {
    for (int j = 0; j < TEXT_LENGTH; ++j) {
      float x0 = text->width * (j + 0.5) / TEXT_LENGTH;
      float y0 = text->height * 0.75 - text->width * 0.5 / TEXT_LENGTH;
      float dx = text->width * 0.5 / TEXT_LENGTH;
      float dy = text->width * 0.5 / TEXT_LENGTH;
      int i = text->textstr[j];
      if ('a' <= i && i <= 'z') {
        i -= 'a';
      } else if ('A' <= i && i <= 'Z') {
        i -= 'A';
      } else {
        i = 255;
      }
      glTexCoord4f( (i % text->fonts.pack)      / (float) text->fonts.pack, ((i ↙
          ↳ / text->fonts.pack) + 1) / (float) text->fonts.pack, 0, 1);
      glVertex2f(x0 - dx, y0 - dy);
      glTexCoord4f(((i % text->fonts.pack) + 1) / (float) text->fonts.pack, ((i ↙
          ↳ / text->fonts.pack) + 1) / (float) text->fonts.pack, 1, 1);
      glVertex2f(x0 + dx, y0 - dy);
      glTexCoord4f(((i % text->fonts.pack) + 1) / (float) text->fonts.pack,  (i ↙
          ↳ / text->fonts.pack)      / (float) text->fonts.pack, 1, 0);
      glVertex2f(x0 + dx, y0 + dy);
      glTexCoord4f( (i % text->fonts.pack)      / (float) text->fonts.pack,  (i ↙
          ↳ / text->fonts.pack)      / (float) text->fonts.pack, 0, 0);
      glVertex2f(x0 - dx, y0 + dy);
    }
  } glEnd();
  glUseProgramObjectARB(0);
  glBindTexture(GL_TEXTURE_2D, 0);
  glDisable(GL_TEXTURE_2D);
}

int text_keynormal(struct text *text, int key, int x, int y) {
  if (('A' <= key && key <= 'Z') || ('a' <= key && key <= 'z') || (key == ' ')) ↙
      ↳ {
    for (int i = 1; i < TEXT_LENGTH; ++i) {
      text->textstr[i-1] = text->textstr[i];
    }
    text->textstr[TEXT_LENGTH-1] = key;
    return 1;
  } else if (('\r' == key) || ('\n' == key)) {
    for (int i = 0; i < TEXT_LENGTH; ++i) {
      text->textstr[i] = ' ';
    }
    return 1;
```

```
  } else if ('\b' == key) {
    for (int i = TEXT_LENGTH - 1; i >= 1; --i) {
      text->textstr[i] = text->textstr[i-1];
    }
    text->textstr[0] = ' ';
    return 1;
  } else {
    return 0;
  }
}

int text_keyspecial(struct text *text, int key, int x, int y) {
  return 0;
}
```

104 src/text.frag

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Shader for text
================================================================ */

uniform sampler2D texture;

void main(void) {
  vec2 p = gl_TexCoord[0].xy;
  vec4 c = vec4(0.0, 1.0, 0.0, 1.0) * texture2D(texture, p).rgba;
  if (c.a < 0.1) {
    discard;
  } else {
    gl_FragColor = c;
  }
}
```

105 src/text.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Text module
================================================================ */

#ifndef TEXT_H
#define TEXT_H 1

#include "shader.h"
#include "fonts.h"

#define TEXT_LENGTH 32

struct text { struct shader shader;
  struct {
    GLint texture; // fragment
```

```
  } uniform;
  struct {
    int texture; // fragment
  } value;
  struct fonts fonts;
  char textstr[TEXT_LENGTH]; // characters to display
  int width;
  int height;
};

struct text *text_init(struct text *text);
void text_reshape(struct text *text, int w, int h);
void text_display(struct text *text);
int text_keynormal(struct text *text, int key, int x, int y);
int text_keyspecial(struct text *text, int key, int x, int y);

#endif
```

106 src/text.vert

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Text vertex shader
================================================================ */

void main(void) {
  gl_TexCoord[0] = gl_MultiTexCoord0;
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```

107 src/timeline.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Timeline module
================================================================ */

#include "timeline.h"

struct timeline *timeline_init(struct timeline *timeline) {
  timeline->state1 = timeline_idle;
  timeline->state = timeline_idle;
  timeline->phase = 0;
  return timeline;
}

void timeline_advance(struct timeline *timeline) {
  timeline->state1 = timeline->state;
  timeline->phase += 0.04;
  switch (timeline->state) {
    case timeline_done: break;
    case timeline_idle: break;
```

```
    case timeline_main: break;
    case timeline_intro1:
      if (! (timeline->phase < TIMELINE_INTRO1_LENGTH)) {
        timeline->phase = 0;
        timeline->state = timeline_intro2;
      }
      break;
    case timeline_intro2:
      if (! (timeline->phase < TIMELINE_INTRO2_LENGTH)) {
        timeline->phase = 0;
        timeline->state = timeline_main;
      }
      break;
    case timeline_outro:
      if (! (timeline->phase < TIMELINE_OUTRO_LENGTH)) {
        timeline->phase = 0;
        timeline->state = timeline_done;
      }
      break;
  }
}

void timeline_start(struct timeline *timeline) {
  timeline->phase = 0;
  timeline->state = timeline_intro1;
}

void timeline_stop(struct timeline *timeline) {
  timeline->phase = 0;
  timeline->state = timeline_outro;
}

/* EOF */
```

108 src/timeline.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2010,2011  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Timeline module
================================================================ */

#ifndef TIMELINE_H
#define TIMELINE_H 1

#define TIMELINE_INTRO1_LENGTH 5
#define TIMELINE_INTRO2_LENGTH 25
#define TIMELINE_OUTRO_LENGTH 30

enum timeline_state {
  timeline_idle,
  timeline_intro1,
  timeline_intro2,
  timeline_main,
  timeline_outro,
  timeline_done
```

```
};

struct timeline {
  enum timeline_state state1, state;
  double phase;
};

struct timeline *timeline_init(struct timeline *timeline);
void timeline_advance(struct timeline *timeline);
void timeline_start(struct timeline *timeline);
void timeline_stop(struct timeline *timeline);

#endif
```

109 src/util.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Utility Functions
================================================================ */

#include <assert.h>
#include "util.h"

//================================================================
// round 'x' up to the nearest power of two (which may be 'x' itself)
unsigned int roundtwo(unsigned int x) {
  assert(x <= 1 << 31); // termination condition
  unsigned int y = 1;
  while (y < x) y <<= 1;
  return y;
}

//================================================================
// find log2 of the nearest power of two above 'x'
unsigned int logtwo(unsigned int x) {
  assert(x <= 1 << 31); // termination condition
  unsigned int y = 1, z = 0;
  while (y < x) { y <<= 1; z += 1; };
  return z;
}

// EOF
```

110 src/util.h

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
Utility Functions
================================================================ */

#ifndef UTIL_H
```

```
#define UTIL_H 1

unsigned int roundtwo(unsigned int x);
unsigned int logtwo(unsigned int x);

#endif
```

111 src/worldsphere.c

```
/* ================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------
World sphere shader
================================================================ */

#include "worldsphere.h"
#include "worldsphere.frag.c"

//================================================================
// worldsphere shader initialization
struct worldsphere *worldsphere_init(struct worldsphere *worldsphere) {
  if (! worldsphere) { return 0; }
  if (! shader_init(&worldsphere->shader, 0, worldsphere_frag)) {
    return 0;
  }
  shader_uniform(worldsphere, texture);
  shader_uniform(worldsphere, rot);
  shader_uniform(worldsphere, size);
  worldsphere->value.texture = 0;
  worldsphere->value.rot[0] = 0;
  worldsphere->value.rot[1] = 0;
  return worldsphere;
}

//================================================================
// worldsphere shader activation
void worldsphere_use(struct worldsphere *worldsphere) {
  if (worldsphere) {
    glUseProgramObjectARB(worldsphere->shader.program);
    shader_updatei(worldsphere, texture);
    shader_updatef2(worldsphere, rot);
    shader_updatef2(worldsphere, size);
  } else {
    glUseProgramObjectARB(0);
  }
}

void worldsphere_idle(struct worldsphere *worldsphere) {
  worldsphere->value.rot[0] += worldsphere->delta[0];
  worldsphere->value.rot[1] += worldsphere->delta[1];
  while (worldsphere->value.rot[0] <  0) worldsphere->value.rot[0] += 1;
  while (worldsphere->value.rot[1] <  0) worldsphere->value.rot[1] += 1;
  while (worldsphere->value.rot[0] >= 1) worldsphere->value.rot[0] -= 1;
  while (worldsphere->value.rot[1] >= 1) worldsphere->value.rot[1] -= 1;
}
```

```
// EOF
```

112 src/worldsphere.frag

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
----------------------------------------------------------------------------
World sphere shader
============================================================================ */

uniform sampler2D texture;
uniform vec2 rot;
uniform vec2 size;

void main(void) {
  vec2 p = gl_TexCoord[0].xy;
  vec2 s = sqrt(0.5) * gl_TexCoord[0].zw;
  float d = dot(s,s);
  vec3 n;
  float a;
  float c;
  if (d < 1.0) {
    c = 1.0;
    a = 1.0;
    n = normalize(vec3(s, sqrt(1.0 - d)));
    p = sqrt(2.0) * s / (1.0 + sqrt(1.0 - d));
  } else {
    c = 0.0;
    a = 0.0;
    n = vec3(0.0, 0.0, 0.0);
  }
  c = c * 0.0625 + pow(dot(vec3(0.0, 0.0, 1.0), n), 2.0);
  p += rot;
  p -= floor(p);
  vec2 p0 = floor(p * size) / size;
  vec2 dp = (p - p0) * size;
  vec3 tl = texture2D(texture, p0).rgb;
  vec3 tr = texture2D(texture, p0 + vec2(1.0/size.x, 0.0       )).rgb;
  vec3 bl = texture2D(texture, p0 + vec2(0.0,        1.0/size.y)).rgb;
  vec3 br = texture2D(texture, p0 + vec2(1.0/size.x, 1.0/size.y)).rgb;
  vec3 t = tl * (1.0 - dp.x) + dp.x * tr;
  vec3 b = bl * (1.0 - dp.x) + dp.x * br;
  vec3 l = tl * (1.0 - dp.y) + dp.y * bl;
  vec3 r = tr * (1.0 - dp.y) + dp.y * br;
  vec3 m1 = t * (1.0 - dp.y) + dp.y * b;
  vec3 m2 = l * (1.0 - dp.x) + dp.x * r;
  vec3 m = 0.5 * (m1 + m2);
  gl_FragColor = vec4(m * c, a);
}
```

113 src/worldsphere.h

```
/* ============================================================================
rdex -- reaction-diffusion explorer
Copyright (C) 2008,2010  Claude Heiland-Allen <claude@mathr.co.uk>
```

```
-------------------------------------------------------------------
World sphere shader
=================================================================== */

#ifndef WORLDSPHERE_H
#define WORLDSPHERE_H 1

#include "shader.h"

//=====================================================================
// borderwindow shader data
struct worldsphere { struct shader shader;
  struct { GLint texture; GLint rot;    GLint size;    } uniform;
  struct { int   texture; float rot[2]; float size[2]; } value;
  float delta[2];
};

//=====================================================================
// prototypes
struct worldsphere *worldsphere_init(struct worldsphere *worldsphere);
void worldsphere_use(struct worldsphere *worldsphere);
void worldsphere_idle(struct worldsphere *worldsphere);

#endif
```

114 start.sh

```
#!/bin/bash
DATE="$(date --iso=s)"
(
  killall light-locker
  xset -dpms
  xset s off
  xrandr --output LVDS-0 --same-as HDMI-0 --scale-from 1920x1080
  while true
  do
    RDEX_UPLOAD="http://rdex/sounding-diy-iii-vm-ml/upload/new" RDEX_SESSION="${↙
        ↳ HOME}/opt/var/rdex/session" "${HOME}/opt/bin/rdex"
    sleep 1
  done &
) > "${HOME}/opt/var/rdex/log/${DATE}.log" 2>&1
```

115 stop.sh

```
#!/bin/bash
killall devilspie
killall jack-rack
killall -HUP ecasound
killall -HUP meterbridge
killall -HUP jackd
killall -HUP qjackctl
killall -HUP top
```

116 TODO

```
rdex-client tickets
```

```
URGENT
------

  * bash any possible NaN/inf to 0 in audio
  * intro sequence
  * outro sequence
  * use vertex arrays instead of immediate mode for ball drawing

TODO
----

  * check audio sample rate / video sample rate interdependence
  * game controller input
  * 8-way nearest neighbour navigation for sequence editing
  * set CPU affinity and performance governors if necessary
  * interpolate textures for audio if not everything
  * attempt to use async PBOs for realtime video recording
  * restore non-realtime rendering
  * fix audio at other than JACK/48000Hz
  * merge from CyPi for loading screen/progress bar
  * incremental library/session loading with progress bar
  * sequencer controls for audio radius/spin/travel/speed/etc
  * keyboard controls for reseed stuff
  * audio waveform / spirograph display overlay
  * fix Makefile dependencies to avoid memory corruption and OS crash
  * use multiple texture tile-sheets to boost ball count limit
  * fill hyperspace with fog/dust/ether
  * alpha blend balls with background for smoother appearance
  * video script option handling for 4:3 vs 16:9 aspect ratio
  * full screen anti-aliasing (render at 2x size, downscale smoothly)
  * interestingness boost by seeing if larger r-d grid works fast enough
  * authentication for upload to server
  * maintain README to be in sync with implementation
  * webpage texts

ONGOING
-------

  * make some videos at various stages of development

LATER
-----

  * motion blur
  * make balls nicely glowing
  * ripples when interesting species found
  * catch libcurl std(out|err) output and use it somehow
    http://curl.haxx.se/libcurl/c/curl_easy_setopt.html#CURLOPTWRITEFUNCTION
  * statistics display in-program
  * use GLEW more sensibly/correctly/etc
  * use OpenGL 2.x variants instead of a mishmash of ARB/EXT stuff
  * investigate OpenGL 3.x/4.x API changes and start updating things
  * Debian/Ubuntu/etc packages
  * select point from library for rendering
  * rdex-remote to handle rdex:// urls from browser for above
```

```
  * interactive camera controls (back to rolling ball?)
  * make camera target have an orientation somehow
  * make camera target spin
  * 4D lighting of worldsphere and balls
  * paint into the reactions
  * add more automation of mode switching ("attract mode")
  * investigate USB game controller support
  * distributed rendering!?
  * rdex.rc for options (eg, session dir and initial fullscreenness)
  * add command line arguments to override environment variables
  * runtime setting of NRT render frame rate (both audio and video)
  * runtime setting of NRT capture intervals (both period and interval)
  * runtime setting of NRT quit when rendering complete
  * runtime setting of display aspect ratio and size
  * lock display size when in NRT mode to avoid accidental mess-ups
  * hyperbolic layout by image similarity
  * download library from server, again with threads
  * download library using bittorrent or other p2p

DONE
----

  * worldsphere size variation over time (2010-09-27)
  * disable screensaver and DPMS etc (2010-09-25)
  * send JACK transport commands on start / stop commands (2010-09-25)
  * investigate sync to vblank (2010-09-25)
  * hide mouse cursor (2010-09-25)
  * fix explore/random mode and generate a new pristine session dir (2010-05-17)
  * CPU to generate coordinate texture for audio.frag lookup (2010-05-14)
  * audio coordinates to vary smoothly over time to reduce glitches (2010-05-14)
    ie: spirograph-style wandering instead of discrete circles
  * audio coordinates to be integrated with overdrive to reduce glitches ↙
    ↳ (2010-05-14)
    ie: grab part of waveform from each overdriven frame
  * quality boost by antialiased downscaling to 64x64 or so for the thumbs ↙
    ↳ (2010-05-14)
    ie: upscale -> false colours -> downscale smoothly
  * improve audio tone smoothness (better interpolation/filtering) [ATi BUG] ↙
    ↳ (2010-05-12)
  * check that the linear interpolation implementation is correct [ATi BUG] ↙
    ↳ (2010-05-12)
  * audio dynamic range compression [using jack-rack] (2010-05-12)
  * window size/aspect appearance independence (seems fixed?) (2010-05-12)
  * worldsphere aspect ratio checkup (is it really circular) (2010-05-12)
  * test 4:3 to see if it looks better than 16:9 [handle both] (2010-05-12)
  * video script should clean up files when complete (2010-05-08)
  * video script should generate an ogv from the mpeg (2010-05-08)
  * space scaling for camera physics as well as ball display (2010-05-06)
  * improve audio change smoothness (more often than display frame rate) ↙
    ↳ (2010-05-05)
  * audio sample rate handling logic (sound should be rate independent) ↙
    ↳ (2010-05-05)
  * speed up by using vertex shaders for projection from 4D (billboarding) ↙
    ↳ (2010-05-04)
  * immersive hyperspace experience (flying around to new worlds) (2010-05-04)
  * speed up by using arrays with large texture containing many small images ↙
    ↳ (2010-04-??)
```

```
  * move image analysis stuff into uploader thread (avoid long pause) ↙
    ↳ (2010-??-??)
  * backport style from current rdex-server (2009-10-27)
  * use threads to upload to server in background (2009-10-18)
  * test on other machines (2009-10-17)
  * rdex server (Python/WSGI) with rdex client and browser clients (2009-04-04)
  * make cute icon! (2009-04-01)
  * random vs search vs what? research, decide! (perturb) (2009-04-01)
  * investigate glut "game mode" instead of "fullscreen" (sucks) (2009-04-01)
  * debug segfault on startup (latest fglrx is fine) (2009-04-01)
  * image texture feature extraction (ripped from FIRE) (2008-11-07)
  * health warning (2008-11-03)
  * hide mouse pointer (2008-11-03)
  * fullscreen mode support (2008-11-03)
  * handle perspective frustrum properly (2008-11-03)
  * debug rolling ball implementation (2008-11-03)
  * rationalize Makefile (2008-11-03)
  * depth sorting of points for library display (2008-11-02)
  * save library to session folder while running (2008-11-02)
  * load library from session folder at startup (2008-11-02)
  * split the behemoth (2008-11-01)

WONT
----

  * interpolate between adjacent frames for even smoother audio
  * audio silence detection -> position randomization
  * space scaling by local ball density (statistics of nearest N balls)
```

117 video.sh

```
#!/bin/bash
MKV="rdex-client-$(date --iso=s | tr ':' '-').mkv"
RDEX_RENDER="1" RDEX_SESSION="./session/" ./src/rdex 2>"${MKV}.log" > "${HOME}/↙
    ↳ out/rec.ppm"
ecasound -f:f32,1,48000 -a 1 -i:audio.l.raw -chmove 1,1 -ea 200 -a 2 -i:audio.r.↙
    ↳ raw -chmove 1,2 -ea 200 -a 1,2 -f:s16_le,2,48000 -o audio.wav &&
ffmpeg -r 25 -f image2pipe -i "${HOME}/out/rec.ppm" -b 5000000 -i audio.wav -ab ↙
    ↳ 192000 "${MKV}"
#ppmtoy4m -S 444 -F 25:1 |
#y4mscaler -I sar=1/1 -O preset=dvd -O yscale=1/1 |
#mpeg2enc -f 8 -q 3 -b 8000 -B 768 -D 9 -g 9 -G 15 -P -R 2 -o video.m2v &&
#ecasound -f:f32,1,48000 -a 1 -i:audio.l.raw -chmove 1,1 -ea 200 -a 2 -i:audio.r↙
    ↳ .raw -chmove 1,2 -ea 200 -a 1,2 -f:s16_le,2,48000 -o audio.wav &&
#twolame -b 224 audio.wav &&
#mplex -f 8 -V -o "${MPEG}" video.m2v audio.mp2 &&
#rm -f video.m2v audio.mp2 audio.wav audio.l.raw audio.r.raw &&
#ffmpeg2theora -p preview "${MKV}"
```

118 xorg.conf

```
# nvidia-settings: X configuration file generated by nvidia-settings
# nvidia-settings:  version 1.0  (buildd@biber)  Tue May 18 10:36:08 UTC 2010

Section "ServerLayout"
    Identifier     "Layout0"
    Screen      0  "Screen0" 0 0
```

```
    Screen      1  "Screen1" RightOf "Screen0"
    InputDevice    "Keyboard0" "CoreKeyboard"
    InputDevice    "Mouse0" "CorePointer"
    Option         "Xinerama" "0"
EndSection

Section "Files"
EndSection

Section "InputDevice"
    # generated from default
    Identifier     "Mouse0"
    Driver         "mouse"
    Option         "Protocol" "auto"
    Option         "Device" "/dev/psaux"
    Option         "Emulate3Buttons" "no"
    Option         "ZAxisMapping" "4 5"
EndSection

Section "InputDevice"
    # generated from default
    Identifier     "Keyboard0"
    Driver         "kbd"
EndSection

Section "Monitor"
    # HorizSync source: edid, VertRefresh source: edid
    Identifier     "Monitor0"
    VendorName     "Unknown"
    ModelName      "Chi Mei Optoelectronics corp."
    HorizSync       30.0 - 75.0
    VertRefresh     60.0
    Option         "DPMS"
EndSection

Section "Monitor"
    # HorizSync source: edid, VertRefresh source: edid
    Identifier     "Monitor1"
    VendorName     "Unknown"
    ModelName      "Idek Iiyama HM903DB/DTB"
    HorizSync       30.0 - 132.0
    VertRefresh     50.0 - 200.0
    Option         "DPMS"
EndSection

Section "Device"
    Identifier     "Device0"
    Driver         "nvidia"
    VendorName     "NVIDIA Corporation"
    BoardName      "GeForce G 105M"
    BusID          "PCI:1:0:0"
    Screen          0
EndSection

Section "Device"
    Identifier     "Device1"
    Driver         "nvidia"
```

```
    VendorName     "NVIDIA Corporation"
    BoardName      "GeForce G 105M"
    BusID          "PCI:1:0:0"
    Screen          1
EndSection

Section "Screen"
    Identifier     "Screen0"
    Device         "Device0"
    Monitor        "Monitor0"
    DefaultDepth    24
    Option         "TwinView" "0"
    Option         "metamodes" "DFP: nvidia-auto-select +0+0"
    SubSection     "Display"
        Depth       24
    EndSubSection
EndSection

Section "Screen"
    Identifier     "Screen1"
    Device         "Device1"
    Monitor        "Monitor1"
    DefaultDepth    24
    Option         "TwinView" "0"
    Option         "TwinViewXineramaInfoOrder" "CRT-0"
    Option         "metamodes" "CRT: 1024x768_85 +0+0; CRT: 1024x768_75 +0+0; ↙
        ↳ CRT: 1024x768 +0+0"
    SubSection     "Display"
        Depth       24
    EndSubSection
EndSection
```