Компьютерная графика реального времени.

URL: http://www.school30.spb.ru/cgsg/cgc/
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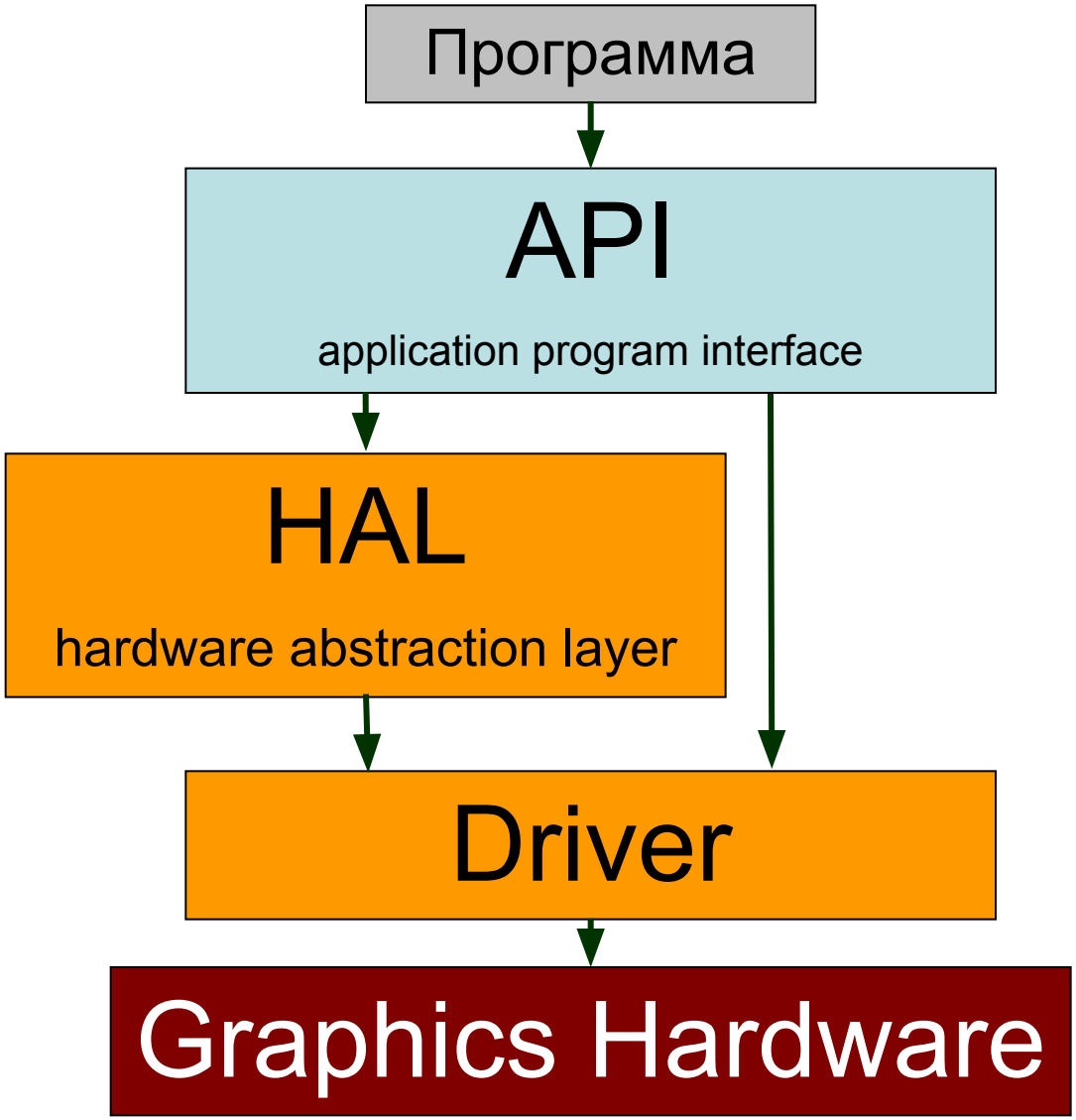
Структура взаимодействия приложения с аппаратурой



- **Open GL** – open graphics library (SGI, 90-е годы, версии 1.0-4.2)
  - GLUT - OpenGL Utility Toolkit (http://www.opengl.org/resources/libraries/glut/)
  - GLEW - OpenGL Extension Wrangler Library (http://glew.sourceforge.net/)
  - GLM - OpenGL Mathematics (http://glm.g-truc.net/)
  - . . .

- **Microsoft Direct3D** – часть MS DirectX (1992 RenderMorphics, версии 2.0-11.0)
  - D3DX – retained mode toolkit
  - XNA - Xbox New Architecture (http://msdn.microsoft.com/ru-ru/xna/)

Инициализация OpenGL


```
PIXELFORMATDESCRIPTOR pfd = {0};

pfd.nSize = sizeof(PIXELFORMATDESCRIPTOR);
pfd.dwFlags =
  PFD_SUPPORT_OPENGL | PFD_SUPPORT_GDI |PFD_DOUBLEBUFFER;
pfd.iPixelType = PFD_TYPE_RGBA;
pfd.cColorBits = 32;
pfd.cDepthBits = 24;
pfd.cStencilBits = 8;

i = ChoosePixelFormat(hDC, &pfd);
DescribePixelFormat(hDC, i, sizeof(PIXELFORMATDESCRIPTOR), &pfd);

SetPixelFormat(hDC, i, &pfd);

hRC = wglCreateContext(hDC);
wglMakeCurrent(hDC, hRC);
```

Инициализация OpenGL: GLUT


```
#include <glut.h>

  glutInitDisplayMode(GLUT_RGBA | GLUT_DOUBLE | GLUT_DEPTH);
  glutInitWindowSize(640, 480);
  glutInitWindowPosition(0, 0);
  glutCreateWindow("OpenGL Sample");

  glutDisplayFunc(Display);
  glutIdleFunc(Idle);
  glutReshapeFunc(Reshape);
  glutKeyboardFunc(Keyboard);

  MyInit();

  glutMainLoop();
```

GLUT: Callbacks

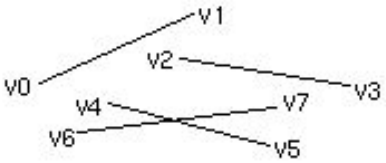

```
void Reshape( int w, int h )
{
  glViewport(0, 0, w, h);
  glMatrixMode(GL_PROJECTION);
  glLoadIdentity();
  gluPerspective(60, (double)w / h, 1, 100);
  gluLookAt(5, 5, 5,   0, 0, 0,   0, 1, 0);
  glMatrixMode(GL_MODELVIEW);
}
void Display( void )
{
  glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);
  . . .
  glFinish();
  glutSwapBuffers();
}
void Idle( void )
{
  glutPostRedisplay();
}
void Keyboard( char key, int x, int y )
{
  if (key == 27)
    exit(0);
}
```

Инициализация Direct3D

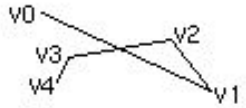

```
IDirect3D9 *D3D;
IDirect3DDevice9 *D3DDev;
D3DPRESENT_PARAMETERS PresParams = {0};
D3DDISPLAYMODE dm;

if ((D3D = Direct3DCreate9(D3D_SDK_VERSION)) == NULL)
  return FALSE;

D3D->GetAdapterDisplayMode(D3DADAPTER_DEFAULT, &dm);

PresParams.Windowed = TRUE;
PresParams.hDeviceWindow = hWnd;
PresParams.BackBufferFormat = dm.Format;
PresParams.BackBufferCount = 1;
PresParams.PresentationInterval = D3DPRESENT_INTERVAL_IMMEDIATE;
PresParams.SwapEffect = D3DSWAPEFFECT_DISCARD;
PresParams.BackBufferWidth = 640;
PresParams.BackBufferHeight = 480;
PresParams.EnableAutoDepthStencil = TRUE;
PresParams.AutoDepthStencilFormat = D3DFMT_D24S8;

if (D3D->CreateDevice(D3DADAPTER_DEFAULT, D3DDEVTYPE_HAL,
      hWnd, D3DCREATE_HARDWARE_VERTEXPROCESSING,
      &PresParams, &D3DDev) != S_OK)
{
  D3D->Release();
  return FALSE;
}
```

Примитивы OpenGL

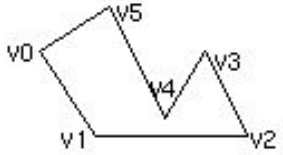
GL_POINTS



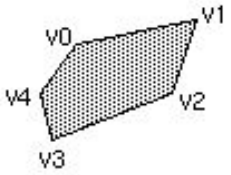
GL_LINES



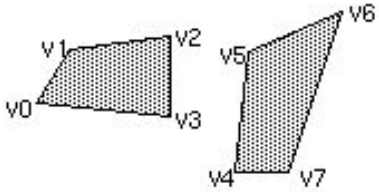
GL_LINE_STRIP



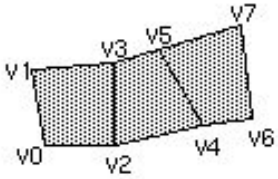
GL_LINE_LOOP



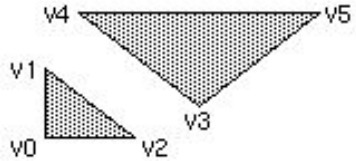
GL_POLYGON



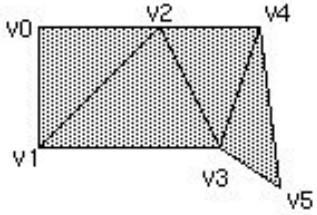
GL_QUADS



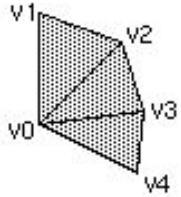
GL_QUAD_STRIP



GL_TRIANGLES



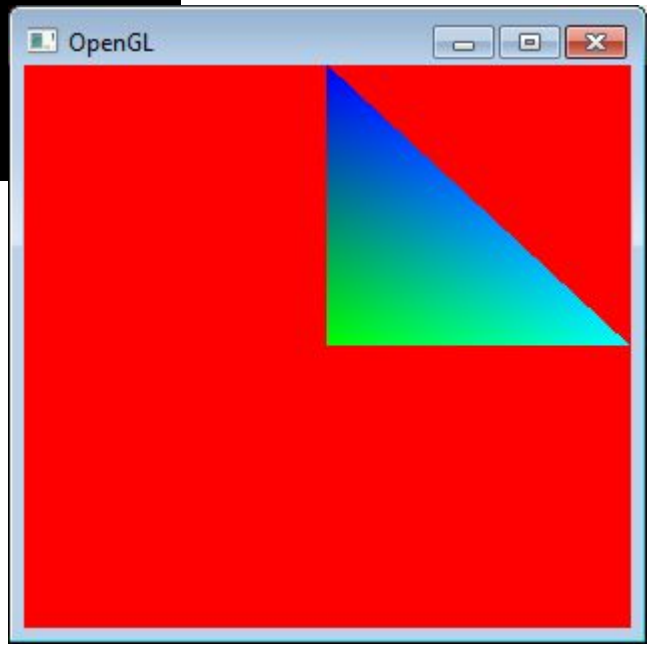
GL_TRIANGLE_STRIP



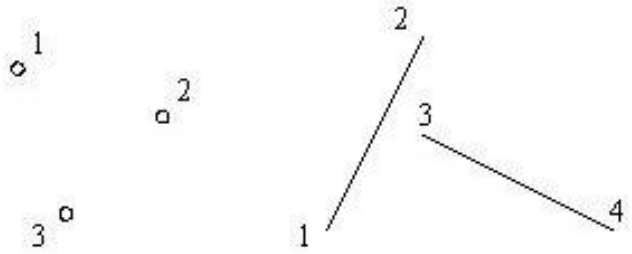
GL_TRIANGLE_FAN

Вывод OpenGL


```
glClearColor(1, 0, 0, 1);
glClear(GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT);

glBegin(GL_TRIANGLES);
  glColor3d(0, 1, 0);
  glVertex3d(0, 0, 0);
  glColor3d(0, 1, 1);
  glVertex3d(1, 0, 0);
  glColor3d(0, 0, 1);
  glVertex3d(0, 1, 0);
glEnd();

glFinish();
glutSwapBuffers();
```

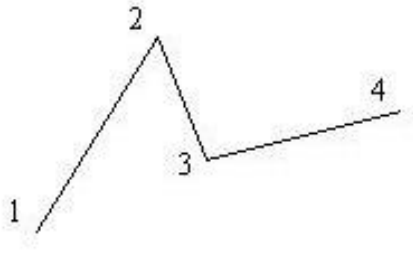


Примитивы Direct3D

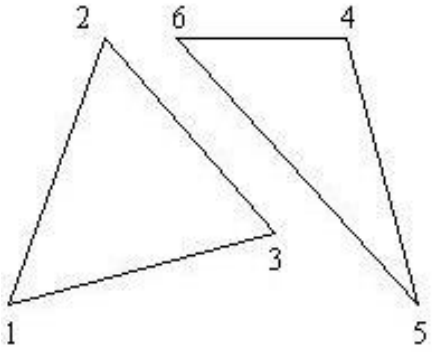


D3DPT_POINTLIST

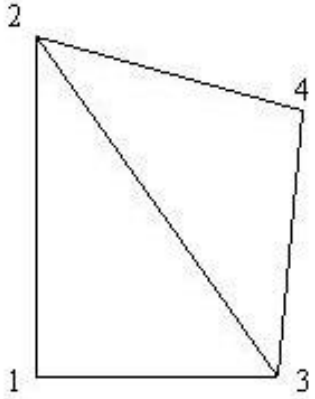
D3DPT_LINELIST



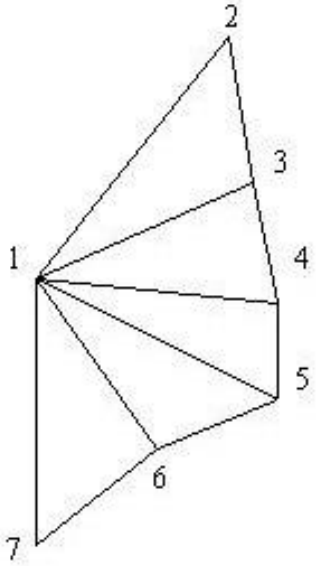
D3DPT_LINESTRIP



D3DPT_TRIANGLELIST



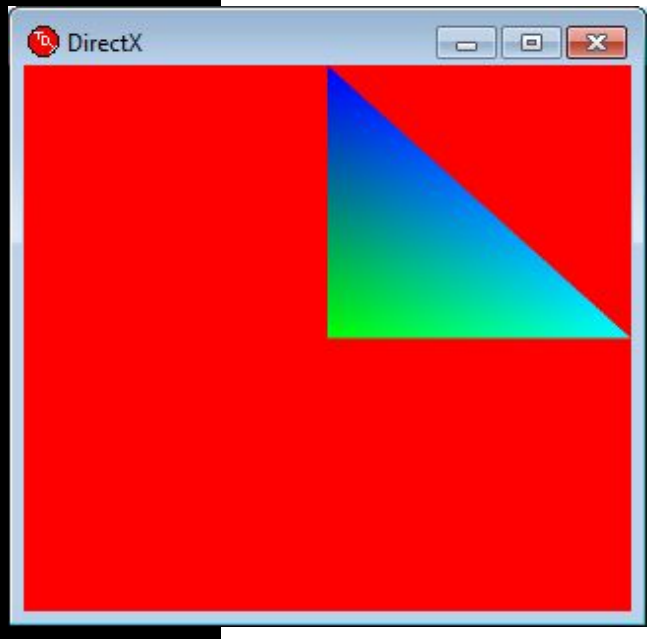
D3DPT_TRIANGLESTRIP



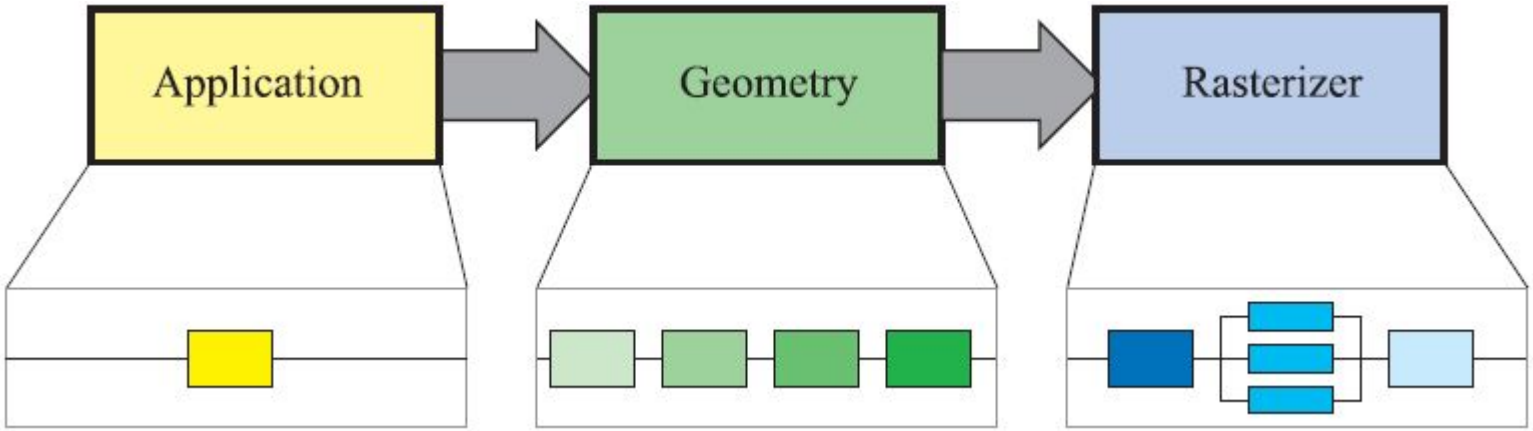
D3DPT_TRIANGLEFAN

Вывод Direct3D


```
D3DDev->SetFVF(D3DFVF_XYZ | D3DFVF_DIFFUSE);
D3DDev->Clear(0, NULL,
  D3DCLEAR_TARGET | D3DCLEAR_STENCIL | D3DCLEAR_ZBUFFER,
  D3DCOLOR_XRGB(255, 0, 0), 1.0, 0);

D3DDev->BeginScene();

D3DDev->SetRenderState(D3DRS_LIGHTING, FALSE);
D3DDev->SetRenderState(D3DRS_CULLMODE, D3DCULL_NONE);

struct VERTEX
{
  FLOAT X, Y, Z;
  DWORD Color;
} pnts[] =
{
  {0, 0, 0, D3DCOLOR_XRGB(0, 255, 0)},
  {1, 0, 0, D3DCOLOR_XRGB(0, 255, 255)},
  {0, 1, 0, D3DCOLOR_XRGB(0, 0, 255)},
};

D3DDev->DrawPrimitiveUP(D3DPT_TRIANGLELIST,
  1, pp, sizeof(VERTEX));

D3DDev->EndScene();
D3DDev->Present(NULL, NULL, NULL, NULL);
```

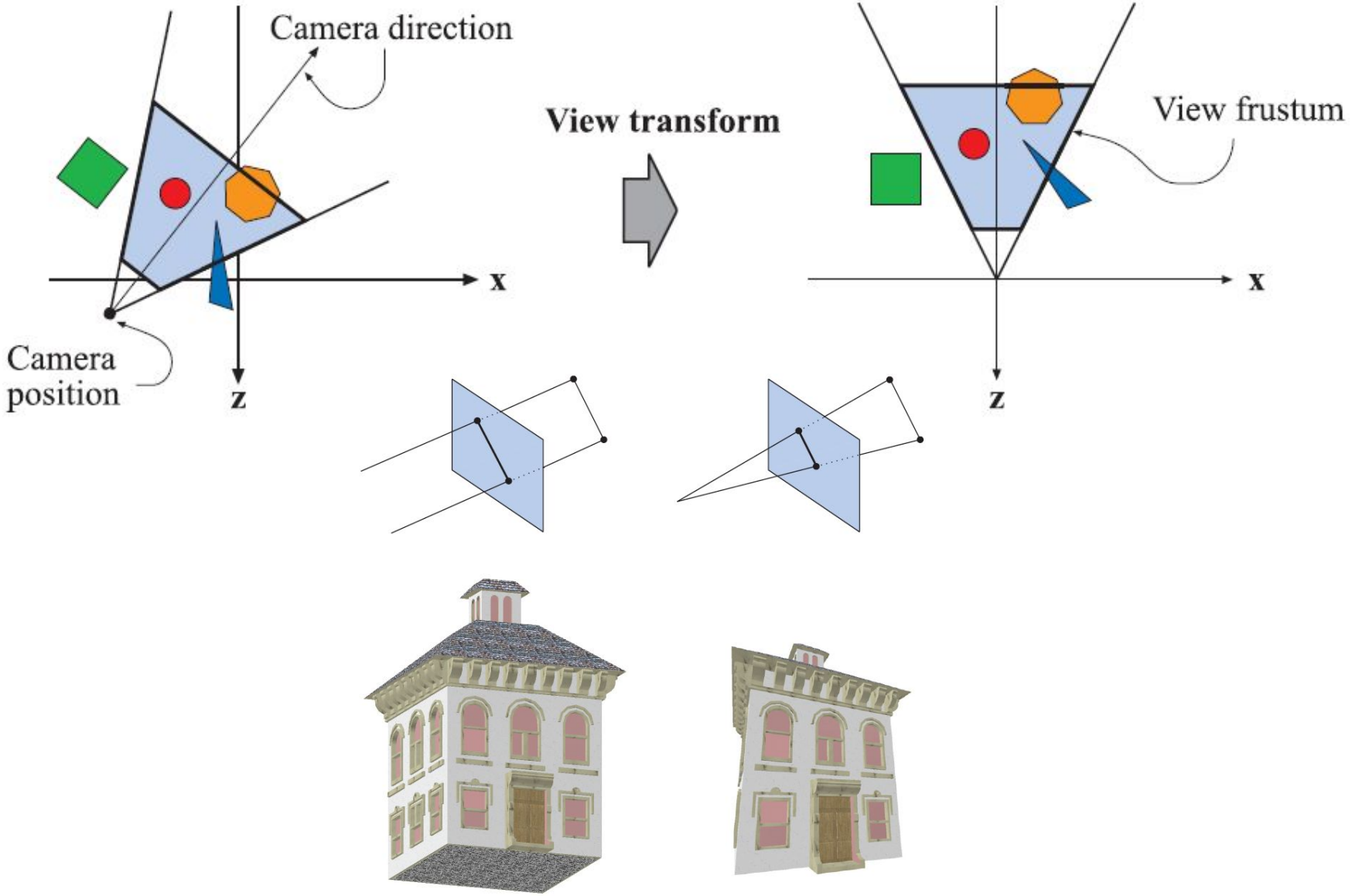


Общая архитектура

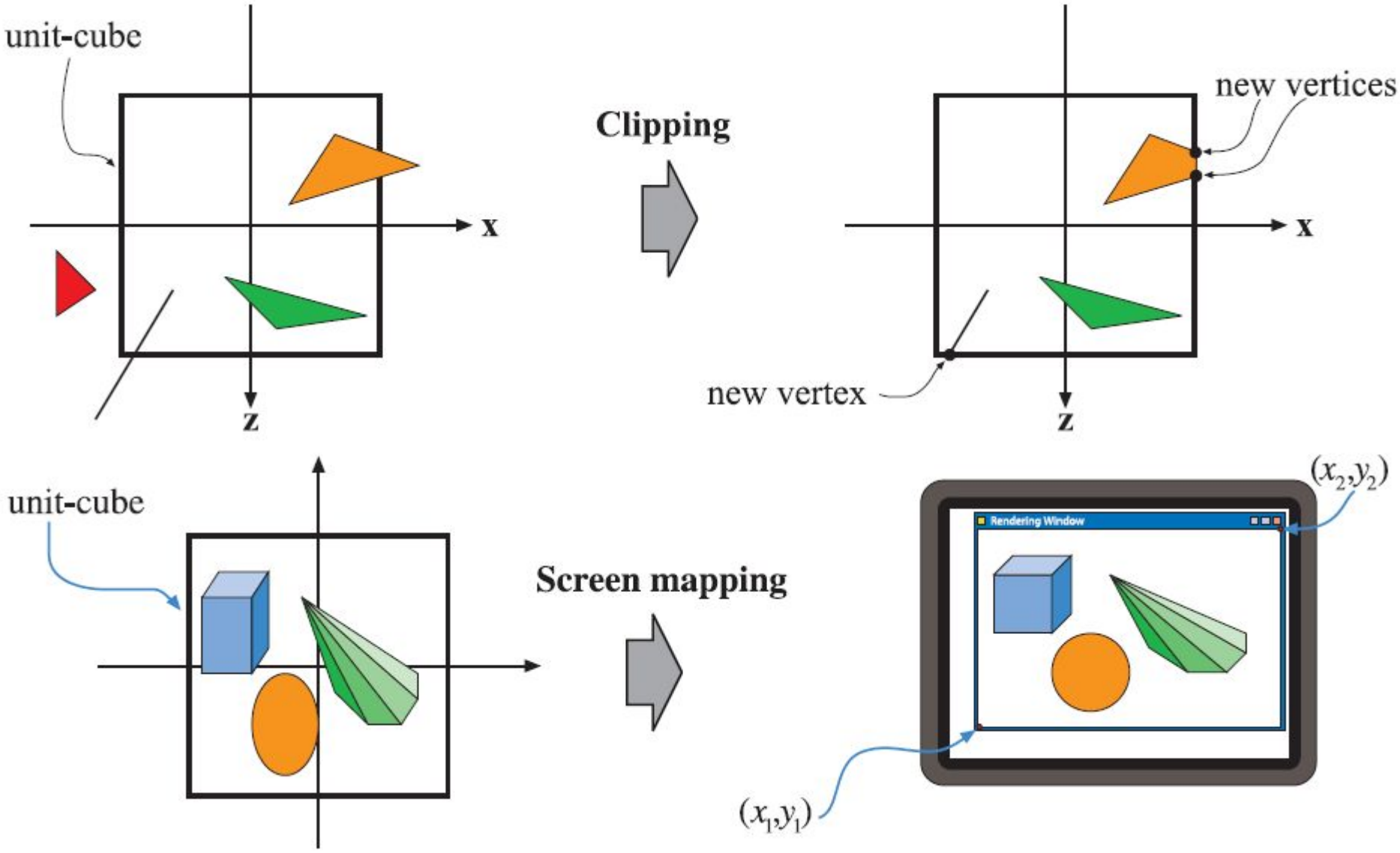


Геометрическая фаза

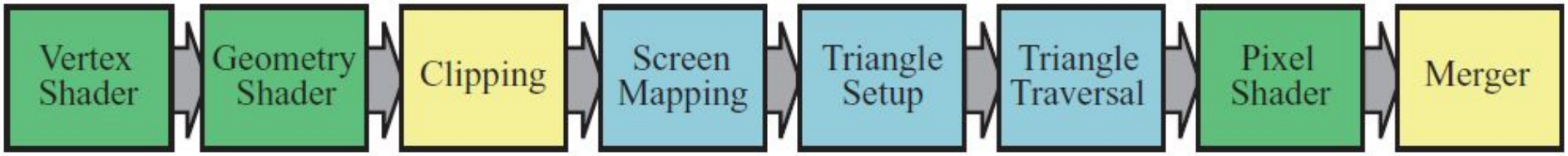
Видовые преобразования & проецирование



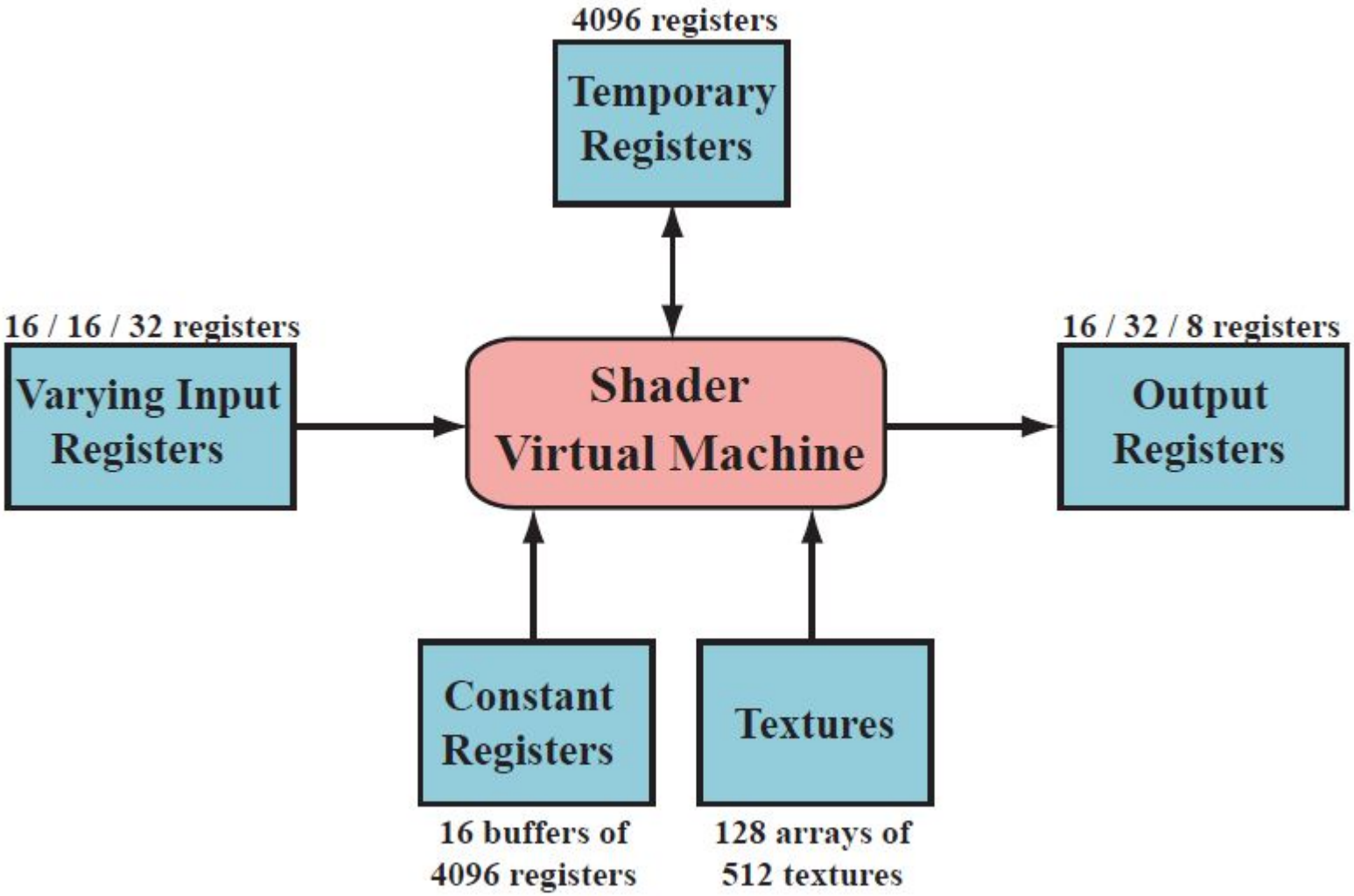
Clip + Screen map



Графический конвейер на GPU



- зеленый – полностью программируемый этап
- желтый – конфигурируемый и непрограммируемый
- синий – полностью фиксированный


4096 registers
Temporary Registers
16 / 16 / 32 registers
Varying Input Registers
Shader Virtual Machine
16 / 32 / 8 registers
Output Registers
Constant Registers
Textures
16 buffers of 4096 registers
128 arrays of 512 textures

Shaders


```
unsigned prg;
. . .
int i;

glUseProgram(prg);
i = glGetUniformLocation(prg, "time");
glUniform1f(i, Time);

glBegin(GL_TRIANGLES);
  glVertex3d(0, 0, 0);
  glVertex3d(1, 0, 0);
  glVertex3d(0, 1, 0);
glEnd();
```

использование

инициализация

```
ShvText = LoadProg("test.glslv");
shv = glCreateShader(GL_VERTEX_SHADER);
glShaderSource(shv, 1, &ShvText, NULL);
glCompileShader(shv);
glGetShaderiv(shv, GL_COMPILE_STATUS, &res);
glGetShaderInfoLog(shv, sizeof(Buf), &len, Buf);

ShfText = LoadProg("test.glslf");
shf = glCreateShader(GL_FRAGMENT_SHADER);
glShaderSource(shf, 1, &ShfText, NULL);
glCompileShader(shf);
glGetShaderiv(shf, GL_COMPILE_STATUS, &res);
glGetShaderInfoLog(shf, sizeof(Buf), &len, Buf);

prg = glCreateProgram();
glAttachShader(prg, shv);
glAttachShader(prg, shf);

glLinkProgram(prg);
glGetProgramiv(prg, GL_LINK_STATUS, &res);
glGetProgramInfoLog(prg, sizeof(Buf), &len, Buf);
```

Shaders: vertex – закраска Гуро


```
// Gouraud
varying out vec4 c;     uniform vec4 spec;
uniform vec3 eyepos;    uniform vec4 diff;
uniform vec4 amb;       uniform float spower;
uniform float time;

void main( void )
{
  vec3 p = vec3(gl_ModelViewMatrix * gl_Vertex); // transformed point to world space
  vec3 campos = vec3(eyepos);                    // camera position
  vec3 l = vec3(sin(time), 0, cos(time));        // vector to light position
  vec3 v = campos - p;                           // vector to the camera
  vec3 n = gl_NormalMatrix * gl_Normal;          // transformed normal
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;

  const vec4 diffcolor = vec4(diff);             // diffuse
  const vec4 speccolor = vec4(spec);             // specular
  const vec4 ambcolor = vec4(amb);               // ambient
  const vec4 specpower = vec4(spower);           // specular power

  vec3 n2 = normalize(n);
  vec3 l2 = normalize(l);
  vec3 v2 = normalize(v);
  vec3 r = reflect(-v2, n2);
  vec4 diff = diffcolor * max(dot(n2, l2), 0.0);
  vec4 spec = speccolor * pow(max(dot(l2, r), 0.0), specpower);

  c = diff + spec + ambcolor;
}
```

Shaders: fragment (pixel) – закраска Гуро


```
// Gouraud
varying in vec4 c;

void main( void )
{
  gl_FragColor = c;
}
```

Shaders: vertex – закраска Фонга

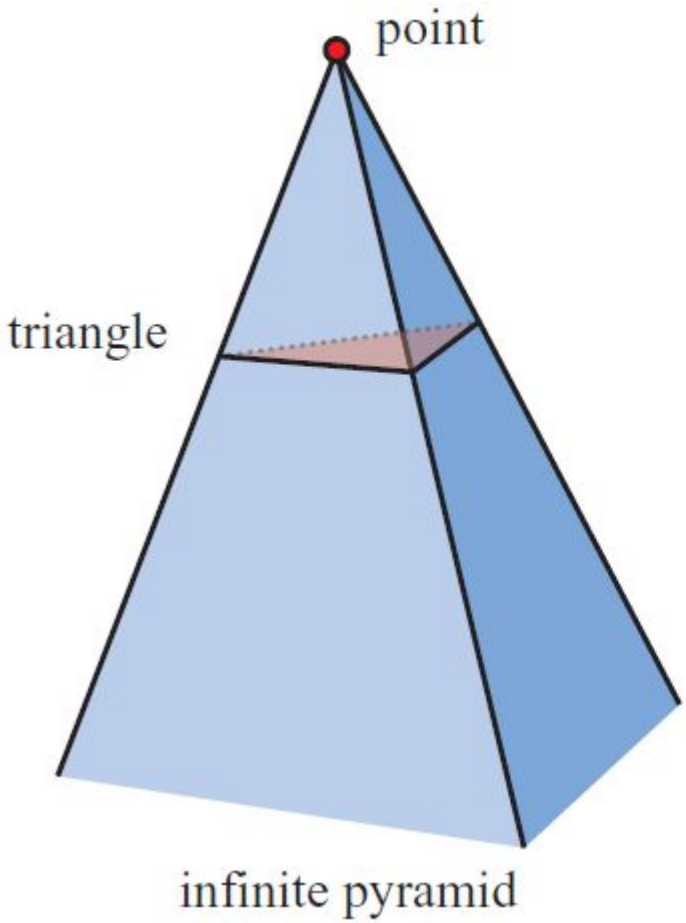

```
// Phong
varying out vec3 l;
varying out vec3 v;
varying out vec3 n;
uniform vec3 eyepos;
uniform float time;

void main( void )
{
  vec3 p = vec3(gl_ModelViewMatrix * gl_Vertex); // transformed point to world space
  vec3 campos = vec3(eyepos);                    // camera position

  l = vec3(sin(time), 0, cos(time));             // vector to light position
  v = campos - p;                                // vector to the camera
  n = gl_NormalMatrix * gl_Normal;               // transformed normal
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```

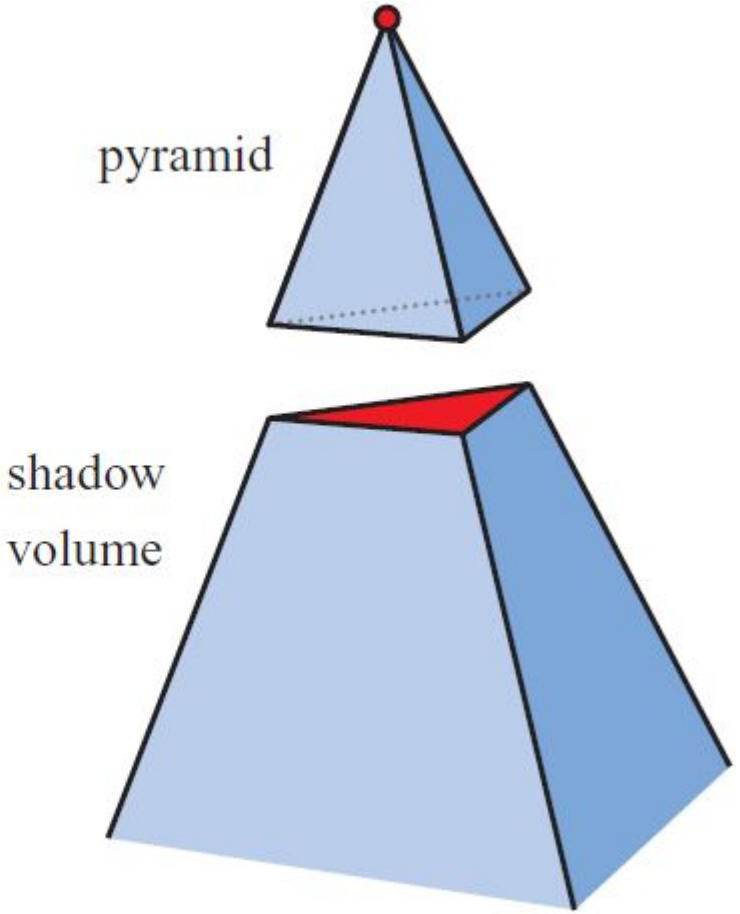
Shaders: fragment (pixel) – закраска Фонга


```
// Phong
varying in vec4 c;

varying in vec3 l;
varying in vec3 v;
varying in vec3 n;
uniform vec4 diff;
uniform vec4 spec;
uniform vec4 amb;
uniform float spower;

void main( void )
{
  const vec4 diffcolor = vec4(diff);   // diffuse
  const vec4 speccolor = vec4(spec);   // specular
  const vec4 ambcolor = vec4(amb);     // ambient
  const vec4 specpower = vec4(spower); // specular power

  vec3 n2 = normalize(n);
  vec3 l2 = normalize(l);
  vec3 v2 = normalize(v);
  vec3 r = reflect(-v2, n2);
  vec4 diff = diff * max(dot(n2, l2), 0.0);
  vec4 spec = spec * pow(max(dot(l2, r), 0.0), spower);

  gl_FragColor = amb + diff + spec;
}
```

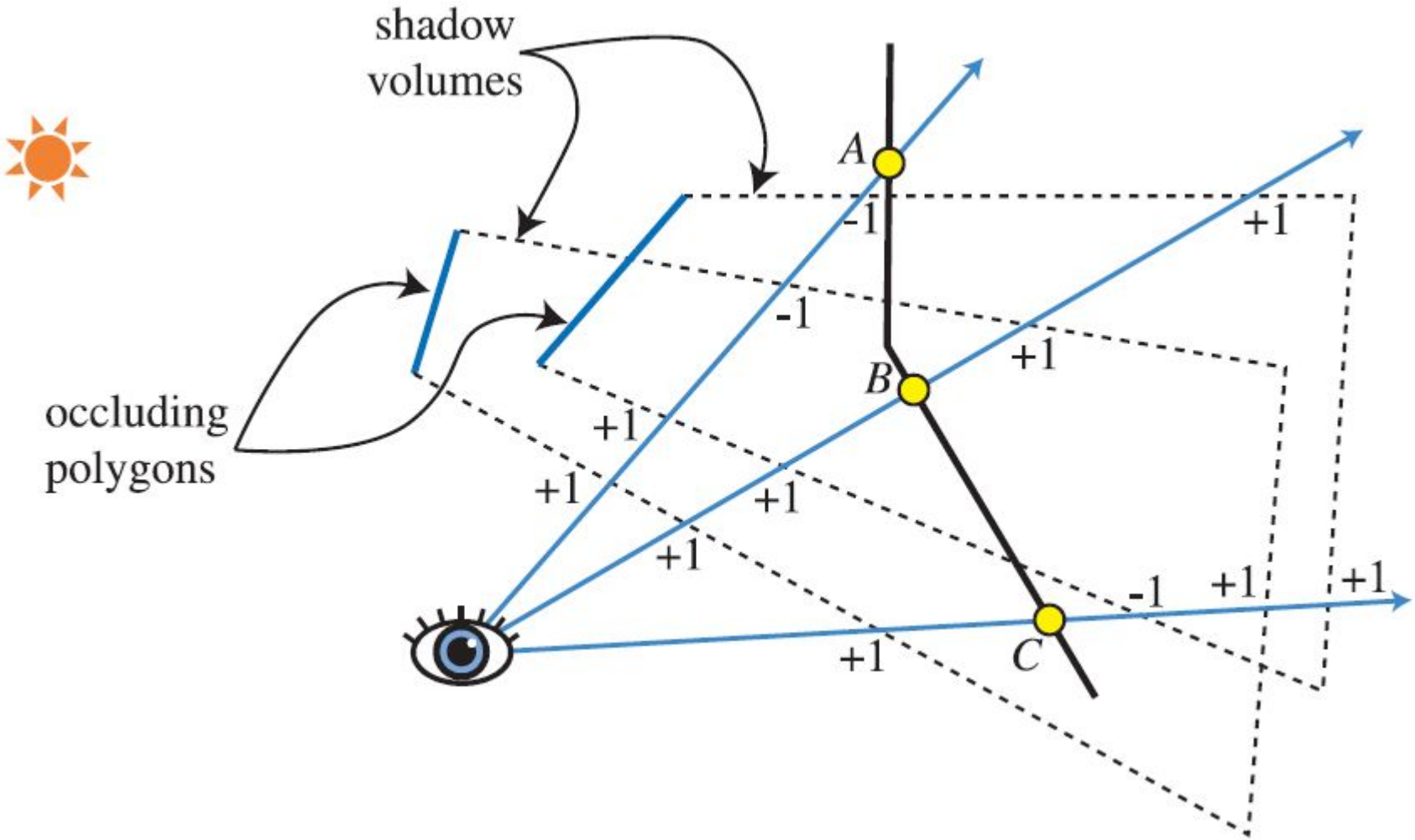
Stencil buffer, blending & alpha test

Stencil buffer: Shadow volume

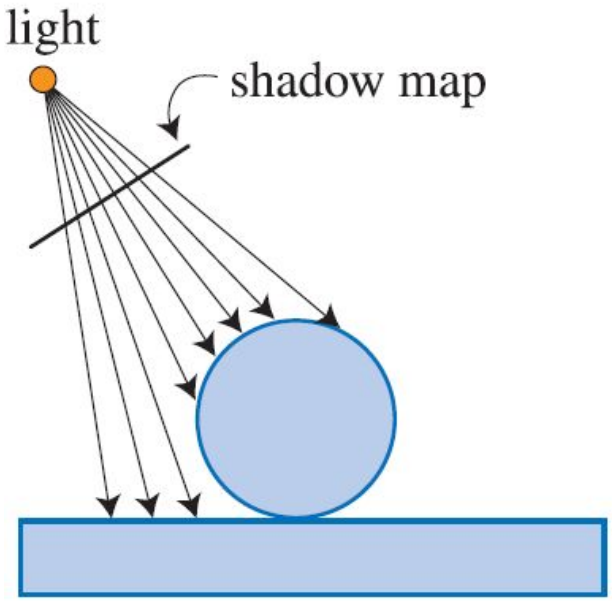


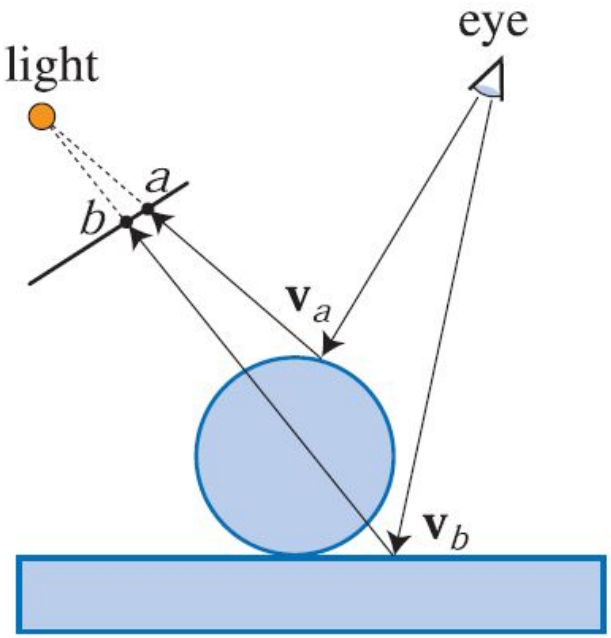


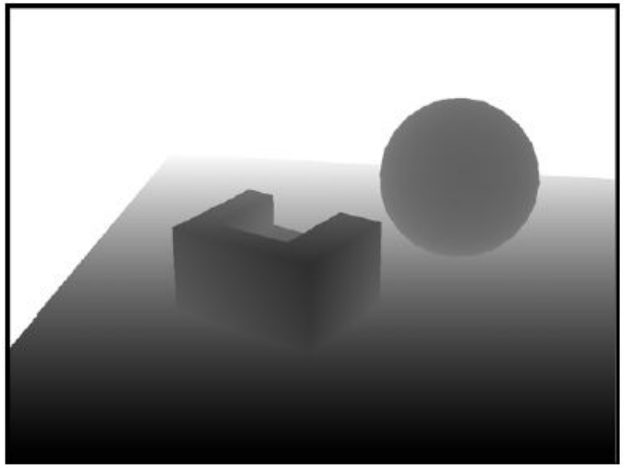
Stencil buffer: Shadow Volume

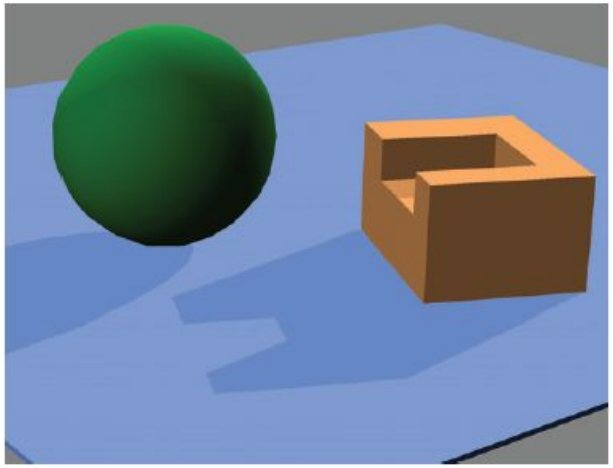


Shadow Map



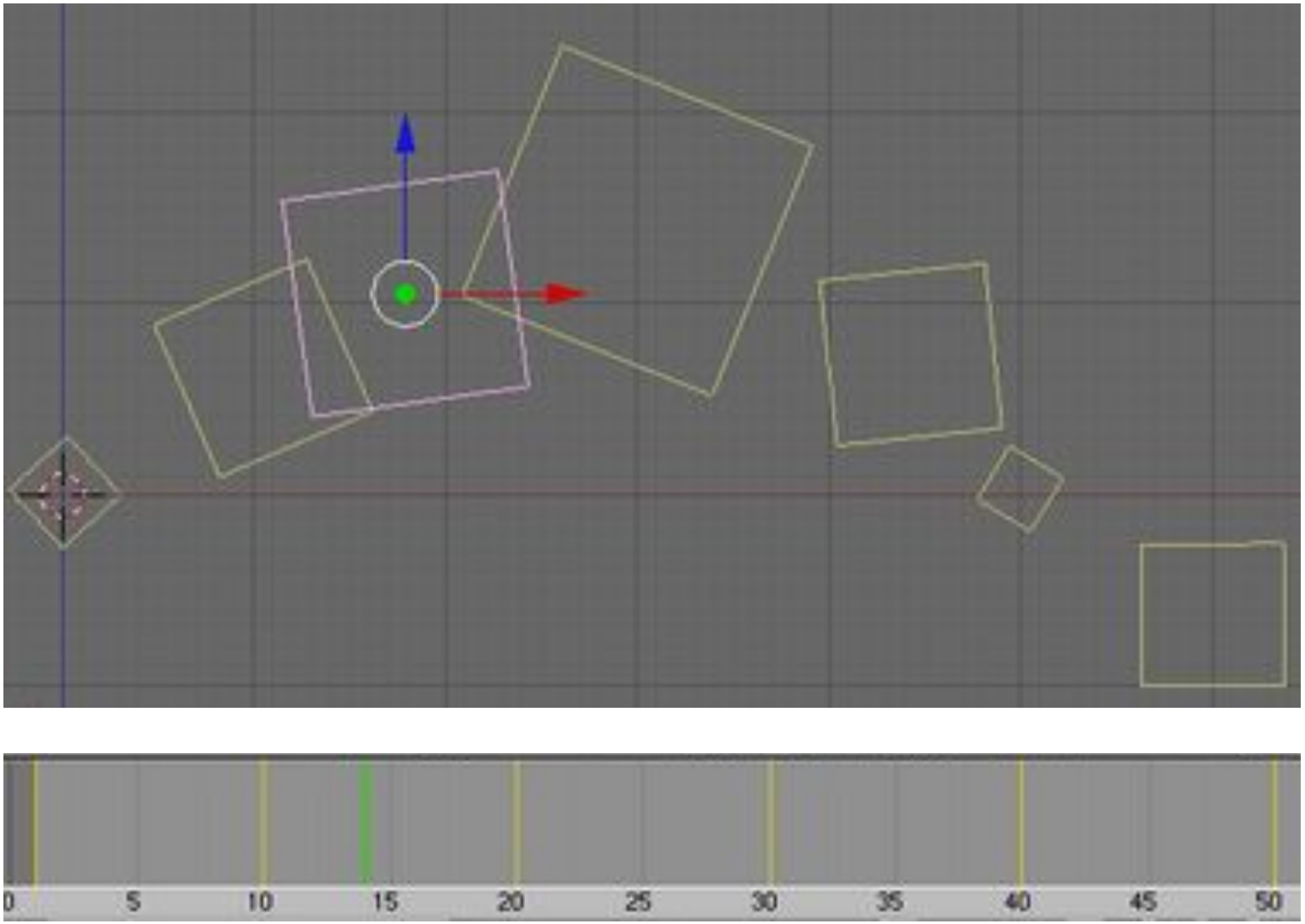




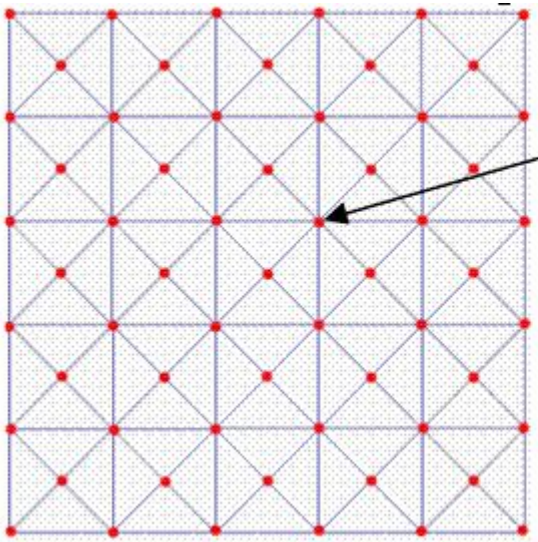


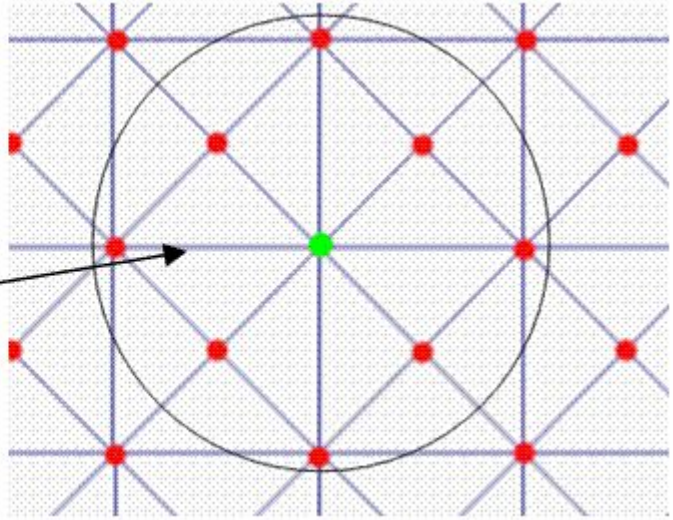
- Синхронизация
  -
```
clock_t start;
. . .
dt = (clock() - start) / (double)CLOCKS_PER_SEC;
```
  -
```
LARGE_INTEGER Start, Quant;
QueryPerformanceFrequency(&Quant);
QueryPerformanceCounter(&Start);
. . .
QueryPerformanceCounter(&Time);
dt = (Time.QuadPart - Start.QuadPart) /
                          (double)Quanty.QuadPart;
```

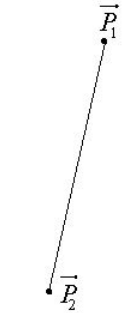
Ключевые кадры (key frame)

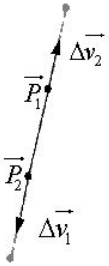


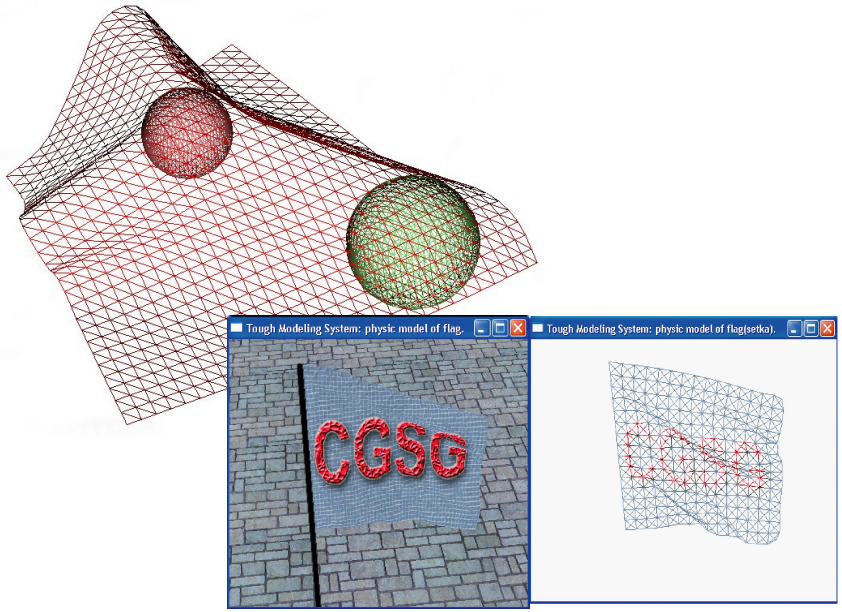
Сеточная анимация



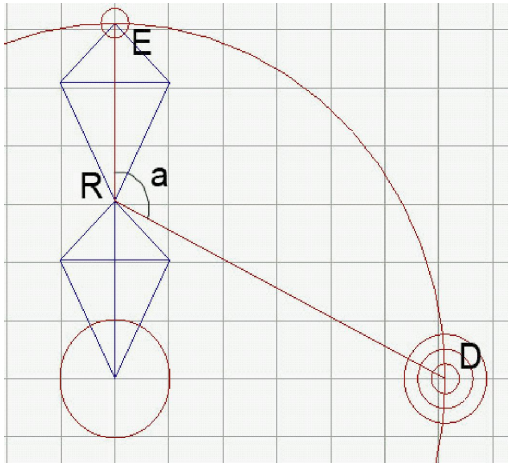


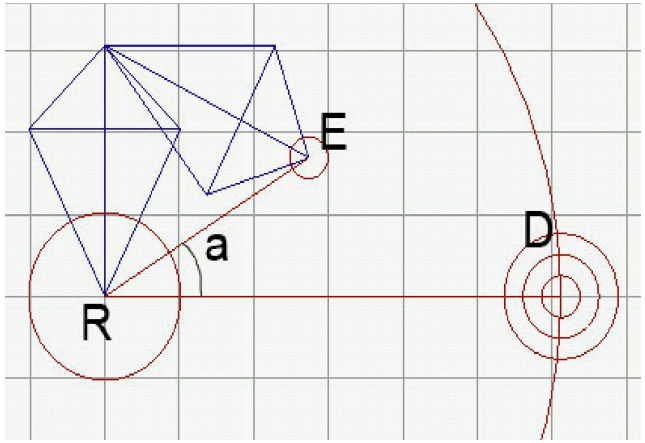


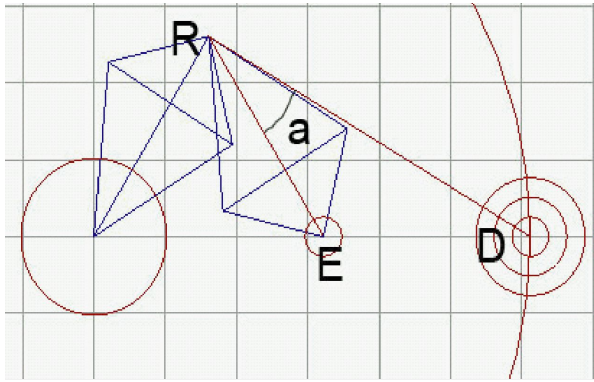


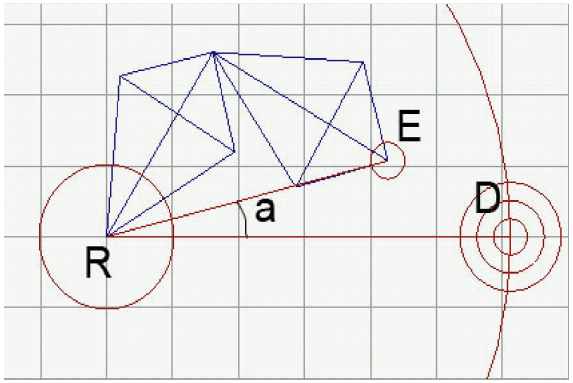


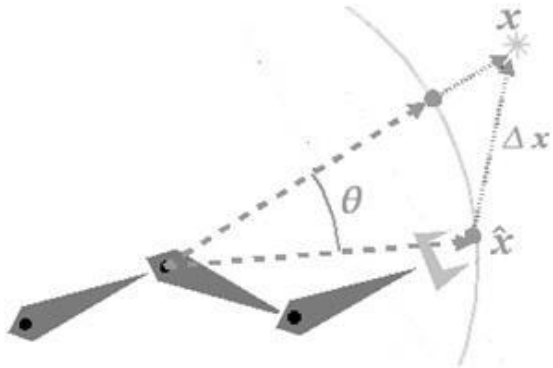
- Cyclic Coordinate Descent (CCD)

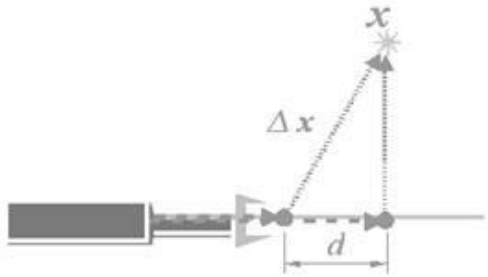


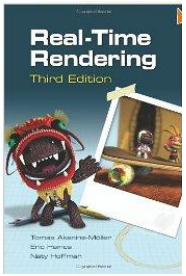












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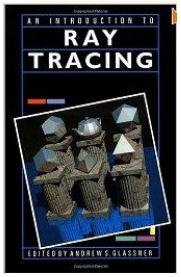

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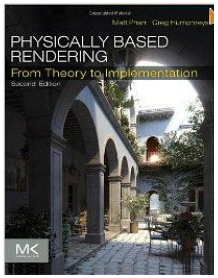

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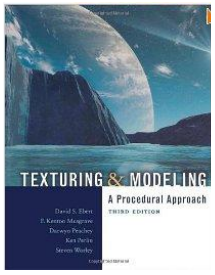

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- Практические задания (до зачетного занятия)
  - Реализовать простейшую анимацию сферы с использованием библиотеки OpenGL или Direct3D (со встроенными в библиотеку возможностями фиксированного конвейера, например, освещения)
  - К предыдущему заданию добавить освещение, реализованное на шейдерах (предпочтительно на фрагментных/пиксельных для поточечного освещения).

В обоих заданиях не использовать retained библиотек (фигуру построить с использованием базовых примитивов).