StimServer

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Contents

1 Error Handling

Error state queries (introduced in version 1.1.5.0) are intended to detect anomalies in the server operation (or bad client requests). *This functionality depends on the detection of all kind of server state problems and badly formated client commands. This is not yet implemented and has to be integrated into future versions of the server.*

2 Photo Diode Signal

A photo diode attached to the display can be used to monitor the timing of the presented stimuli. For this purpose the StimServer can generate a photo diode signal (a small rectangular area typically located in a corner of the screen) that can be drawn either black or white.

In general the photo diode signal is shown in the upper left corner of the screen. In the time domain, this position corresponds to the start of the frame currently being drawn. Starting with version 1.4 of the server, the position of the signal can be changed through an entry in the computer specific part of the Windows Registry.

3 Stimuli

3.1 Pictures

Pictures may be loaded from files of various image formats. They are displayed in their native (pixel-) size. Transparency is supported. Global properties that may be altered are orientation angle and overall transparency.

⋮

3.2 Particle Stimuli

Particle stimuli are composed of a given set of dots (particles) which move in a certain direction with a given speed. The positions of the dots (and optionally the direction of movement per particle) are read from a binary file. The first two rows (in Matlab) of the file contain the normalized x- and y-coordinates (single floats in the range $-1 \ldots +1$). The file may also contain a third row specifying the direction of movement for each particle (angles in degrees as single floats). Dots moving out of the rectangular viewport (specified at the creation of the object) wrap to the opposite edge. The viewport can be masked with a circular and/or Gaussian patch (see below).

To create a coordinate file for a particle stimulus object of 100 random dots with Matlab, you might use

```
NumericBinaryFile('temp.part',2.0*rand(2, 100, 'single')-1.0);
```

The particles of such a file all move according to the direction and speed parameters set for the stimulus object.

To create a similar file where each particle moves into a distinct direction (between -5° and 5° in this example) you may use

```
NumericBinaryFile('temp3.part', vertcat( ...
    2.0*rand(2, 100, 'single')-1.0, 10.0*rand(1, 100, 'single')-5.0));
```

In this mode the value of the direction parameter will be added to the angles read from the file, i.e. in the given example, if you set the direction parameter to 45, the particles will move in directions between 40° and 50°.

3.2.1 Patches for Particle Stimuli

You can use a circular and/or Gaussian patch. With a circular patch any particles outside a circle with a given radius are unvisible.

With a Gaussian patch the transparency of a particle will increase with it's distance from the center of the stimulus. The opacity value α of a particle with distance d from the center of the stimulus is

$$\alpha = e^{-\frac{d^2}{2R^2}}$$

where R is the "radius" parameter set for the patch.

...

3.3 Bitmap Brush Objects

"Bitmap Brush Objects" (introduced in version 1.1.2.0) provide a way to apply "Opacity Masks" to images. There are different modes depending on the size of the components involved.

If the width and height of the opacity mask are smaller than the respective dimensions of the bitmap brush, a centered rectangular part of the bitmap brush with the size of the opacity mask is used for the operation. You may shift the rectangle relative to the bitmap brush. This is the preferred mode of operation.

If the width and height of the opacity mask are greater than the respective dimensions of the bitmap brush used, a centered subset of the same size as the target is used as the mask. Making the opacity mask sufficiently large (twice the size of the bitmap brush) allows the mask to be shifted relative to the target.

You can replace an opacity mask by simply loading a new one. Bitmap brushes without an attached opacity mask render like normal pictures (but more expensive).

3.4 Pixel Shaded Pictures

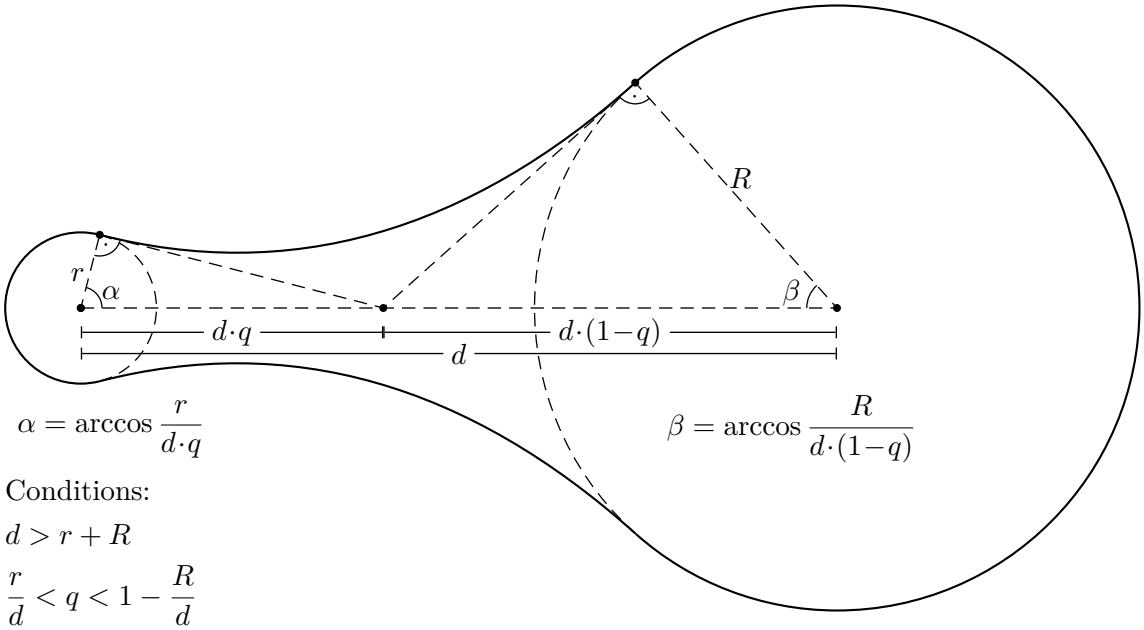
Introduced in version 1.1.4.0 these objects extend the power of pixel shaders to pictures. These stimuli are created in two steps. The first step is to load a normal picture object. In the second step a pixel shader file is loaded. This second command has a reference to the key of the picture object on which the shader will operate. An internal copy of the original picture will be created. Therefore the picture object might be deleted afterwards (if it's not going to be used otherwise).

3.5 Motion Pictures

This stimulus shows a sequence of pictures stored in a `.gif` of `.tif` file. The frame rate can be reduced to an integer fraction of the refresh rate of the display device. The video memory of the system is easily exhausted when using large (picture size and/or number of pictures) sequences. *Try to avoid using this stimulus whenever possible.*

3.6 Petals

Shape made out of two circular arcs and two quadratic Bézier curves.



$\alpha = \arccos \frac{r}{d \cdot q}$

$\beta = \arccos \frac{R}{d \cdot (1-q)}$

Conditions:

$d > r + R$

$\frac{r}{d} < q < 1 - \frac{R}{d}$

4 Animations

Animations change a certain property (e.g. position) of a stimulus object with each frame. Currently only absolute stimulus positions can be specified. The position set for the stimulus object is overwritten.

Animations start as soon as they are assigned to an enabled stimulus object. If an animaton is assigned to a disabled object it starts when the stimulus is enabled. The behaviour at the end of the animation depends on the setting of the "terminal action" (see section C.1 on page 14) at the time the animations ends. The default is that the animation will be deassigned from the stimulus. If a stimulus with an active animation is disabled the animation will stop and be resumed as soon as the stimulus is enabled again.

Terminal Actions: There are various actions that can be executed when an animation completes (see section C.1 on page 14). One of them is "signal an event". Use the `OpenEventA` function with the event name `StimServerAnimationDone` to get a handle to the event. You can then use `WaitForSingleObject` to wait for the event to be signaled or to check it's current state.

4.1 General Motion Paths

With this animation an arbitrary motion path can be read from a binary file. In Matlab you can create files by calling `NumericBinaryFile` with a `single(2,n)` array. The array has to contain pixel coordinates for each frame.

4.2 Straight Line Segment Motion Paths

With this animation the assigned object is moved along a polygon defined through its vertices. The speed of the motion is constant along the entire polygon and is specified at animation creation.

4.3 Linear Ranges

This animation changes a single parameter linearily between a start and an end value within a given time. See page 9 for details.

4.4 Flashes

This animation simply runs for a given number of frames. One application is to display a stimulus for a short time (some frames). Assign the animation to a disabled stimulus and then enable the stimulus (with "disable stimulus bit" of the final action mask set). Another application is to simply signal an event after a given number of frames ($n-1$)).

If you toggle the photo diode it will change before the last frame of the animation is shown.

4.5 Flicker

This animation repeatedly turns a stimulus on and off for a given number of frames. The on and off periods are independent of each other. This animation is infinite in nature and does not obey any final action settings.

4.6 External Position Control

This animation positions a stimulus according to the coordinates provided by an external process through a named shared memory section. The name of the shared memory is supplied at animation creation. The animation is infinite in nature and does not obey any final action settings.

A General Commands

`[00 0]` delete all stimuli (except photo diode signal)

`[00 0 e]` enable (`e=1`) or disable (`e=0`) photo diode signal. On server startup the signal is enabled and black.

`[00 0 0 e]` enable (`e=1`) or disable (`e=0`) all stimuli (except photo diode signal)

`[00 0 1 p]` protect (`p=1`) or unprotect (`p=0`) all stimuli (except photo diode signal). A protected stimulus is unaffected by "delete all", "enable all" and "disable all" commands. The photo diode signal is always protected.

`[00 0 r g b]` set screen background. `r`, `g`, `b` = 0 . . . 255 (unsigned)

`[00 1 0]` end deferred mode (and apply all changes)

`[00 1 1]` start deferred mode

`[00 1 2]` query performance counter (read 8 bytes as an uint64 after issuing this command)

`[00 1 3 a]` set the default "terminal action" for animations. Newly created animations will inherit this setting. Refer to section C.1 on page 14 for details.

`[00 1 4]` query and reset the global error state of the server (read the error mask as an uint16 after issuing this command). A value of 0 for the error mask indicates that no errors were detected by the server. The respective bits of the mask indicate:

1 general server errors occured – query the error code for detail (see below)
2 stimulus errors occured – query the stimuli for detailed information
4 animation errors occured – query animations for detailed information

`[00 1 5 r g b` α`]` set the default draw color. All color components are uint8 (0. . . 255). Newly created particle, symbol, rectangle, petal, ellipse and wedge stimuli will inherit this setting. The initial color is opaque white. Some stimuli may use a separate outline color (see `[00 1 9 ...]`).

`[00 1 6]` query performance frequency (read 8 bytes as an uint64 after issuing this command). This command is intended for the case that the StimServer runs on a different machine. Else it's more efficient to call QueryPerformanceFrequency in the kernel32.dll directly.

`[00 1 7]` query and reset the error code for the most recent general error of the server (read the error state as an uint16 after issuing this command). A value of 0 for the error state indicates that no general server errors were detected.

`[00 1 8]` query the physical frame rate of the presentation device (read 4 bytes as a single float after issuing this command).

`[00 1 9 r g b` α`]` set the default outline color. All color components are uint8 (0. . . 255). Newly created rectangle, petal, ellipse and wedge stimuli will inherit this setting. The initial color is opaque black.

`[00 16 0]` turn photo diode signal off (black)

`[00 16 1]` turn photo diode signal on (white)

`[00 16 2]` toggle photo diode signal

`[00 16 3]` turn on photo diode signal flicker mode (toggles with each frame)

`[00 16 3 p]` position the photo diode signal in the upper (`p=0`) or lower (`p=1`) left corner. This command is not deferrable.

A.1 Stimulus Creation

After sending a stimulus creation command you have to read 2 bytes (as a 16 bit unsigned integer) from the pipe. This number will be 0 if an error occured during stimulus creation. Otherwise the key (`kk`) of the newly created stimulus will be returned.

These commands are not deferrable.

`[00 2 filename]` create a picture stimulus from the specified image file.

`[00 3 kk filename]` create or replace with a picture stimulus from the specified image file.

`[00 4 filename]` create a pixel shader stimulus from the specified HLSL file.

`[00 5 kk filename]` create or replace with a pixel shader stimulus from the specified HLSL file.

`[00 8 w h filename]` create a particle stimulus (size `w`×`h` pixels) from the specified file. `w` and `h` are uint16. For example Matlab code to create a coordinate file see section 3.2 on page 3. *Note: The ability to set w and h independently is intended for future expansions to rectangular stimuli. The current implementation is designed for stimuli with a square layout, i.e. w and h should be equal.*

`[00 9 w h kk filename]` create or replace with a particle stimulus from the specified file.

`[00 10]` create a pixel stimulus.

`[00 11 kk]` create or replace with a pixel stimulus.

`[00 12 t s]` create a symbol stimulus of type `t` (uint8) and size `s` (uint16). The size specifies the width and the height of the symbol.

`t`	symbol type
1	filled circle
2	outlined circle

`[00 13 t s kk]` create or replace symbol stimulus of type `t` and size `s`.

`[00 14 filename]` create a bitmap brush from the specified image file.

`[00 15 kk filename]` create or replace with a bitmap brush from the specified image file.

`[00 18 kk filename]` create a pixel shader stimulus from the specified HLSL file. The shader is expected to operate on an existing picture object identified through the key `kk`. See section 3.4 on page 4 for details.

`[00 20]` create a rectangle stimulus. Default is a rectangle filled with the "default draw color".

`[00 24 filename]` create a "motion picture" stimulus from the specified image file.

`[00 26]` create a "petal" stimulus (see section 3.6 on page 4). Default is a petal filled with the "default draw color".

`[00 28]` create an ellipse stimulus. Default is an ellipse filled with the "default draw color".

`[00 30]` create a "wedge" stimulus. Default is a filled wedge with a center angle of 9°.

A.2 Animation Creation

After sending an animation creation command you have to read 2 bytes (as a 16 bit unsigned integer) from the pipe. This number will be 0 if an error occured during animation creation. Otherwise the key (`ka`) of the newly created animation will be returned.

These commands are not deferrable.

`[00 130 filename]` create a motion path from the specified binary file. In Matlab you can create files by calling `NumericBinaryFile` with a `single(2,n)` array. The array should contain pixel coordinates for each frame.

`[00 132 vv]` create a straight line segment motion path object. `vv` is the velocity in pixels per second (16 bit unsigned integer). For information on how to specify the path and start the animation see C.2 on page 14.

`[00 136 start end duration m]` create a linear range animation where a single float parameter changes from a given start value to an end value in a given period of time (`duration` in seconds as a single float). `m` is the `uint8` mode. It's meaning is context dependent.

For pictures the change of the global alpha value is supported. The `start` and `end` values must be between `0.0` (transparent) and `1.0` (opaque). The mode (`m`) has to be `1`.

For wedges the change of the angle (orientation) is supported. The `start` and `end` values denote angles in degrees. The mode (`m`) has to be `1`.

For pixel shader stimuli `m` denotes the number of a scalar parameter.

If you try to run this animation with other stimuli or modes then a message is displayed in the output window and the animation is deassigned from the stimulus.

`[00 138 nn]` create a flash animation object for `nn` frames (16 bit unsigned integer).

`[00 138 nn mm]` create a flicker animation object where a stimulus is repeatedly enabled for `nn` frames and then disabled for `mm` frames. (`nn` and `mm` are 16 bit unsigned integers).

[00 140 memMapName] create an external position control animation. The `memMapName` specifies the name of the controlling shared memory section (which must provide two single floats specifying the position coordinates).

B Stimulus Commands

B.1 General Stimulus Commands

[kk 0] remove (destroy) stimulus (not deferrable)

[kk 0 e] enable (`e=1`) or disable (`e=0`) stimulus

[kk 3 p] protect (`p=1`) or unprotect (`p=0`) stimulus (see section A on page 6)

[kk 3 x y] move (center of) stimulus to `x`, `y` (single floats)

[kk 7] query and reset error state of stimulus (not deferrable). You have to read the error code as an uint16 after issuing this command. A value of 0 for the error state indicates that no errors were detected for this stimulus.

[kk 8] query the position of the stimulus (not deferrable). You have to read the position as two single floats after issuing this command. With Matlab you can read an `uint64` and then `typecast` to `'single'`.

This command is particularly useful while an animation is running. It will reflect the actual position of the stimulus (independent of "deferred mode").

[kk 14] bring stimulus to front (drawn last). This command will change the key of the stimulus. You have to read the new key (as a 16 bit unsigned integer) after issuing this command.

[kk 14 ks] Swap the keys (and thus the drawing order) of two stimuli.

B.2 Outline Commands

Several stimuli (rectangle, petal and ellipse) can be drawn width an optional outline. Those stimuli share the following commands:

[kk 6 mode] set draw mode (uint8, default 1):

- **1** draw a filled shape
- **2** draw an outlined shape
- **3** draw a filled shape with outline

[kk 9 r g b α**]** set components (uint8, $0 \ldots 255$) for the outline color of the shape. (The initial color is inherited from the "default outline color".)

[kk 10 linewidth] set line width (single float, default 2) of the outline.

B.3 Picture Commands

[kk 1 α**]** set global alpha value for picture ($\alpha = 0 \ldots 255$, uint8)

[kk 2 i] set increment value for picture rotation to `i` (`i` $= -128 \ldots 127$)

[kk 4 φ**]** set orientation of picture. φ is a single float specifying the angle in degrees.

B.4 Pixel Shader Commands

[kk 1 i value] set `value` (single float) for parameter `i` of shader

[kk 2 value] set animation increment `value` (single float) for shader (speed)

[kk 5 i r g b α**]** set components ($0 \ldots 255$) for color `i` of shader (`i` $= 1 \ldots 4$)

[kk 6 value] set animated `value` (single float) for shader

[kk 9 width height] set stimulus size for shader. `width` and `height` are uint16. *This command is valid only for shader programs in the "new" format (see page 16).*

B.5 Particle Stimulus Commands

[kk 1 1 value] set particle diameter (uint16 — initial value is 4)

[kk 1 2 value] set patch radius ($0 \ldots 1.42$ single float) for particle stimulus. A value of 0 switches back to the unpatched (rectangular) mode.

[kk 1 3 value] set Gaussian patch (single float) for particle stimulus. A value of 0 disables the Gaussian patch. For details see section 3.2.1 on page 3.

[kk 2 velocity] set velocity (single float) for particles. The velocity is expressed as the (normalized) coordinate increment per frame.

[kk 4 angle] set angle (degrees as single float) of particle movement. If each particle has it's own angle (see section 3.2 on page 3) this value is added to each of them. *In general the position of a particle is not preserved when the angle is changed.*

[kk 5 r g b α**]** set components (uint8, $0 \ldots 255$) for color of particles. (The initial color is inherited from the "default draw color".)

[kk 6 value] set animated shift value (single float).

B.6 Symbol Commands

[kk 1 1 value] set symbol size (uint16)

[kk 5 r g b α**]** set components (uint8, $0 \ldots 255$) for color of symbol. (The initial color is inherited from the "default draw color".)

This command is not yet implemented for outlined circles.

B.7 Bitmap Brush Commands

[kk 10] remove (destroy) opacity mask (not deferrable)

[kk 10 e] enable (`e=1`) or disable (`e=0`) opacity mask

[kk 11 filename] load an opacity mask for the bitmap brush from the specified image file.

[kk 13 x y] move opacity mask relative to bitmap brush (`x` and `y` are single precision floats)

B.8 Pixel Shaded Picture Commands

[kk 1 i value] set `value` (single float) for parameter `i` of shader

[kk 2 value] set animation increment `value` (single float) for shader (speed)

[kk 6 value] set animated `value` (single float) for shader

B.9 Rectangle Commands

In addition to the following commands you can use the "Outline Commands" described in section B.2 on page 10.

[kk 1 1 width height] set rectangle's size (uint16s). Initial size is 11×21 pixels.

[kk 4 φ] set orientation of rectangle. φ is a single float specifying the angle in degrees.

[kk 5 r g b α] set components (uint8, $0 \ldots 255$) for the fill color of rectangle. (The initial color is inherited from the "default draw color".)

B.10 Motion Picture Commands

In addition to the commands for a picture stimulus (see section B.3 on page 11), the following commands are supported:

[kk 6 n] select frame `n` as the current frame. `n` is a `uint32` starting at 0. Make sure `n` is a valid frame number

[kk 9 nn] set the number of frames a picture is displayed before advancing to the next picture. The default setting is 1, i. e. a new picture is selected with each frame. When this parameter is set to 0, the currently selected picture is displayed permanently. `nn` is a `uint16`.

B.11 Petal Commands

In addition to the following commands you can use the "Outline Commands" described in section B.2 on page 10.

[kk 1 1 r] set radius r to `r` (single float, default 25).

[kk 1 2 R] set radius R to `R` (single float, default 100).

[kk 1 3 d] set distance d to `d` (single float, default 250).

[kk 1 4 q] set q to `q` (single float, default 0.3819660113).

[kk 4 φ**]** set orientation of the petal. φ is a single float (default 0) specifying the angle in degrees.

[kk 5 r g b α**]** set components (uint8, $0 \ldots 255$) for the fill color of the petal. (The initial color is inherited from the "default draw color".)

B.12 Ellipse Commands

In addition to the following commands you can use the "Outline Commands" described in section B.2 on page 10.

[kk 1 1 width height] set ellipse's size (uint16s). Initial size is 100×100 pixels.

[kk 4 φ**]** set orientation of the ellipse. φ is a single float (default 0) specifying the angle in degrees.

[kk 5 r g b α**]** set components (uint8, $0 \ldots 255$) for the fill color of the ellipse. (The initial color is inherited from the "default draw color".)

B.13 Wedge Commands

In addition to the following commands you can use the "Outline Commands" described in section B.2 on page 10.

[kk 1 1 gamma] set center angle of wedge to `gamma` (single float, default 9).

[kk 4 φ**]** set orientation of the wedge. φ is a single float (default 0) specifying the angle in degrees. This parameter can be controlled through a linear range animation (mode=1).

[kk 5 r g b α**]** set components (uint8, $0 \ldots 255$) for the fill color of the wedge. (The initial color is inherited from the "default draw color".)

C Animation Commands

C.1 General Animation Commands

[ka 0] remove (destroy) animation (not deferrable)

[ka 0 a] define the terminal action for the animation. `a` is a uint8 bit mask. The bits have the following meaning:

1	disable the assigned stimulus
2	
4	toggle the photodiode signal[1]
8	signal an event (see section 4 on page 5)
16	restart animation (cyclic execution)
32	reverse animation[2]
64	goto initial state[2]
128	end deferred mode

Setting `a` to 0 restores the default behaviour of simply deassigning the animation from the stimulus.

Newly created animations inherit the "default terminal action mask" (see page 7).

Do not use "toggle the photodiode signal" together with "end deferred mode". Instead use "end deferred mode" only and toggle the photodiode while in deferred mode".

For unknown reasons some deferred commands (e.g. change symbol size) do not work as expected with "end deferred mode".

[ka 0 e kk] assign (`e=1`) or deassign (`e=0`) animation `ka` to/from stimulus `kk`

[ka 7] query and reset error state of animation (not deferrable). You have to read the error code as an uint16 after issuing this command. A value of 0 for the error state indicates that no errors were detected for this animation.

C.2 Straight Line Segments Animation Commands

[ka 11 vertices] set the vertex coordinates of the straight line segment motion path. `vertices` are 16 bit signed integers in pixel space. The animation starts instantly if it's already assigned to a stimulus – else it starts once it is assigned. *The maximum number of vertices to be specified with this command is 31.*

C.3 Flash Animation Commands

[ka 2 nn] set number of frames (`nn` is a 16 bit unsigned integer)

[1] irrespective of "deferred mode"
[2] Not implemented yet.

C.4 External Position Control Animation Commands

`[ka 3 x y]` set position offset coordinates (single floats). The offset is added to the coordinates provided through shared memory.

D Error Codes

D.1 General Error Codes

1 Error creating stimulus (see log window for details).

2 Command for non existing stimulus object (see log window for details).

3 Trying to assign non existing picture object to pixel shader (see log window for details).

4 Compilation of a shader file failed – the stimulus is not created (see log window for details).

5 Trying to create a symbol of size 0 – the stimulus is not created.

6 Trying to create a particle stimulus with width or height equal to 0 – the stimulus is not created.

D.2 Stimulus Error Codes

1 Error reading Opacity Mask file for Bitmap Brush stimulus.

2 Command length error. The command was ignored. See log window for details.

3 Invalid command error. The command was ignored. See log window for details.

4 Trying to set particle or symbol size to 0. The command was ignored.

5 Trying to set the frame number of a Motion Picture stimulus to an invalid number (greater than or equal to the number of frames of the stimulus). The command was ignored.

D.3 Animation Error Codes

2 Command length error. The command was ignored. See log window for details.

E Pixel Shaders

In StimServer versions prior to version 1.2 the size of the stimulus had to be specified in the shader source code. Also these global variables (width and height) had to be used within the shader in a non trivial way. Otherwise the compiler would optimize them out. Example for a simple grating:

```
extern float width  = 166.0f;
extern float height = 166.0f;

cbuffer PS_ANIMATION : register (b1)
{
    float  phase : packoffset(c0.x);
};

cbuffer PS_CONSTANT_BUFFER : register (b0)
{
    float2 center : packoffset(c0.x);
    float  orientation : packoffset(c0.z); // param 1
    float  cycle       : packoffset(c0.w); // param 2
    float4 dummy1      : packoffset(c1.x); // params 3-6
    float4 dummy2      : packoffset(c2.x); // params 7-10
};

float4 PSmain( float4 Pos : SV_POSITION ) : SV_Target
{
    if (distance(center, Pos.xy) > 83.0f) discard;
    static const float pi = 3.141592654;

    float2 p;
    sincos(radians(orientation), p.y, p.x);
    float bright = width-height +
        (sin( phase + dot(center-Pos.xy,p)*(2.0f*pi)/(cycle ? cycle : 14.0f)) + 1.0f)/2.0f;
    return float4( bright, bright, bright, 1.0f );
}
```

Starting with version 1.3 this shader format is not supported anymore.

Begining with version 1.2 of the StimServer the size of the stimulus can be set with a separate command and is then provided to the shader through the `PS_CONSTANT_BUFFER`. The shader above could then look like this

```
cbuffer PS_ANIMATION : register (b1)
{
    float  phase : packoffset(c0.x);
};

cbuffer PS_CONSTANT_BUFFER : register (b0)
{
    float2 center : packoffset(c0.x);
    float  width  : packoffset(c0.z);
    float  height : packoffset(c0.w);
    float  orientation : packoffset(c1.x); // param 1
    float  cycle  : packoffset(c1.y); // param  2
    float2 dummy1 : packoffset(c1.z); // params 3-4
    float4 dummy2 : packoffset(c2.x); // params 5-8
};
```

```
float4 PSmain( float4 Pos : SV_POSITION ) : SV_Target
{
    if (distance(center, Pos.xy) > width/2.0f) discard;
    static const float pi = 3.141592654;

    float2 p;
    sincos(radians(orientation), p.y, p.x);
    float bright =
        (sin( phase + dot(center-Pos.xy,p)*(2.0f*pi)/(cycle ? cycle : 14.0f)) + 1.0f)/2.0f;
    return float4( bright, bright, bright, 1.0f );
}
```

F Program Structure

The actual functionality of the program is achieved by two threads that are executed independently from each other and from the main window of the application. Currently the application window basically provides no functionality other than hosting a log window for informational and error messages (ideally this window should stay blank while the program is running). The additional threads are

The Command Thread listens for commands sent over the command pipe from the controlling program. It then either executes those commands immediately or sets up data structures which will instruct the display thread to do so.

The Display Thread advances any assigned animations and does the actual drawing of the stimuli.