

# Standalone Interactive Graphics (SIG) Toolkit

Copyright (c) 2017-onwards Marcelo Kallmann

## 1 Introduction

SIG is a class toolkit for the development of interactive 3D graphics applications. SIG is designed to be small, flexible, fast, portable, and standalone. It is fully written in C++ but with moderate use of C++ most recent features. SIG does not use STL classes. While STL will most likely be used in your programs, SIG only relies on its internal classes for data structures, leading to more legible compiler error messages, consistent behavior across different compilers, faster compilation, and improved execution times in some cases.

SIG includes a simple and extendible scene graph, a flexible skeleton structure supporting a variety of joint definitions, classes for loading and manipulating `.bvh` motion files, several utilities for developing motion planners, and an analytical Inverse Kinematics solver [1]. It also includes functionality to manage resources such as textures and fonts. SIG is completely standalone, exposing the entire process of using OpenGL, making it a great tool for research and for learning computer graphics. Previous versions of SIG existed under different names and have been used to support a variety of research projects.

**DISTRIBUTION NOTE:** SIG is being prepared for open source release but is not yet available from a public repository. I am still working on some of its basic functionality and library structure. At this point please do not distribute this version outside of class.

### 1.1 Code Structure

SIG is currently divided in 4 libraries: sig, sigogl, sigos, and sigkin. The source files in each library are divided in modules identified by the first 2 letters of each file. An overview of the modules is available in Table 1.

Lib	Module	Description	Examples
sig	gs	generic graphics and system classes	<code>GsVec</code> , <code>GsMat</code> , <code>GsOutput</code> , <code>GsArray</code>
sig	sn	scene graph nodes	<code>SnModel</code> , <code>SnLines</code> , <code>SnTransform</code>
sig	sa	scene graph actions	<code>SaBBox</code> , <code>SaRenderMode</code>
sig	cd	interface to external collision detectors	<code>CdImplementation</code> , <code>CdManager</code>
sigkin	kn	kinematics of articulated structures	<code>KnJoint</code> , <code>KnSkeleton</code> , <code>KnMotion</code>
sigogl	gl	OpenGL-related functions and classes	<code>GlProgram</code> , <code>GlTexture</code>
sigogl	glr	scene node renderers based on OpenGL	<code>GlrMode</code> , <code>GlrLines</code> , <code>GlrText</code>
sigogl	ui	OpenGL-rendered GUI classes	<code>UiButton</code> , <code>UiStyle</code> , <code>UiManager</code>
sigogl	ws	Window system classes	<code>WsWindow</code> , <code>WsViewer</code>
sigos	ws	OS-specific window system interface	<code>wsi_get_ogl_procedure()</code>

Table 1: Libraries and modules in SIG.

SIG follows a simple yet consistent naming convention which is briefly described in `gs.h`. While it is a bit different than modern conventions, it has proven to be effective over the many years it has been used.

### 1.2 Compilation and Supported Systems

SIG is mostly being developed in MS Windows. Project files for Visual Studio Community 2017 are provided to compile all libraries and as well several examples.

Makefiles for Linux are included but they do not yet compile the modules depending on OpenGL. An extension based on `glfw` is currently being developed in order to support Linux and other system.

### 1.3 A First SIG Application

Starting a SIG application is as simple as declaring a viewer and a scene, and then checking events, for example with `ws_run()`. See example in Listing 1 and its result in Figure 1.

Listing 1: My first SIG application.

```
# include <sig/sn_primitive.h>
# include <sigogl/ws_viewer.h>
# include <sigogl/ws_run.h>

int main ( int argc, char** argv )
{
    WsViewer* v = new WsViewer ( -1, -1, 640, 480, "My_First_SIG_APP" );

    SnPrimitive* p = new SnPrimitive ( GsPrimitive::Capsule, 5.0f, 5.0f, 9.0f );
    p->prim().nfaces = 100;
    p->prim().material.diffuse = GsColor::darkred;
    v->rootg()->add ( p );
    v->cmd ( WsViewer::VCmdAxis );
    v->cmd ( WsViewer::VCmdStatistics );
    v->view_all ();
    v->show ();

    ws_run ();
    return 1;
}
```

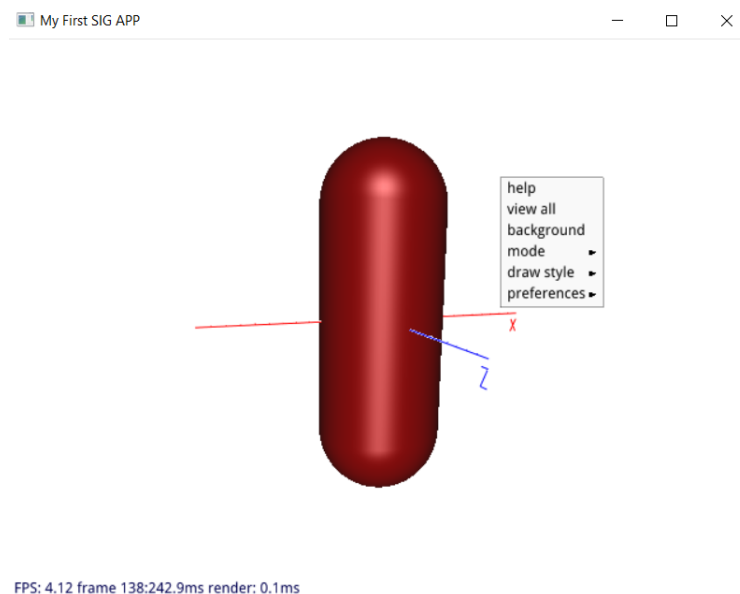


Figure 1: Result of the example in Listing 1.

In most cases however the user will derive `WsViewer` with its own viewer class in order to catch GUI events and extend additional functionality by overriding the virtual methods of `WsViewer`.

When working on your own projects you may use as starting point the project in `sigapp.7z`, which is included in the `examples/` folder of the distribution. This project demonstrates how to declare a simple

scene graph and GUI, how to respond to events, and one possible way to control the main loop for a simple animation. For compilation the project should be placed in the same folder as `sig/`, because the libraries are linked with relative paths.

Multiple examples are also available in the SIG distribution:

- `cameratest`: example manipulations with the camera transformation;
- `customnode`: example of how to build your own scene node and node renderer;
- `fontgen`: example of how to test and define new fonts;
- `gstests`: examples and tests with the many classes in the `gs` module;
- `modelviewer`: example application to view and inspect models, and load `.obj` files;
- `polyeditor`: example of how to use the polygon editor scene node;
- `scenetest`: example testing several scene graph features;
- `shapes`: example program where all types of shapes can be tested;
- `skelviewer`: example application to view skeletons and motions;
- `uidemo`: example application testing every GUI element class.

These example applications demonstrate how the main SIG features should be used.

Some of the examples are in active development in order to become tools to support the development of SIG applications.

## 1.4 File Formats

A number of SIG classes have their own file formats for saving and loading data:

- `GsModel` file format `.m`
- `KnSkeleton` file format `.s`
- `KnSkeleton` data file format `.sd`
- `KnPosture` file format `.sp`
- `KnMotion` file format `.sm`

A description of each file format is available in the Appendix of this document.

## 2 Overview of Main Classes

### 2.1 Arrays and other Data Structures

One of the most used classes is **GsArray**, which is an important class designed to efficiently manipulate memory blocks. The class works similarly to `std::vector` of the standard template library. However it has a main difference: it manipulates the internal data of the array as non-typed memory blocks, so the elements of the array are not treated as objects and the constructors and destructors of the elements in the array are never called when the array is manipulated. **GsArray** relies on low-level C functions for memory allocation, re-allocation, and deletion. Therefore **GsArray** is an efficient memory management class which outperforms `std::vector` in several operations.

The user needs however to pay attention to only use it with primitive types, or for pointers to objects with the use of **GsArrayPt**. See `gs_array.h` for details.

It is also important to observe that **GsArray** automatically doubles its internal memory when it needs more space in certain operations. So references to objects in the array will only be guaranteed to be valid while no new elements are added to the array. For example, a command sequence like `int& e=array[0]; array.push()=5;` should never be written because when 5 is pushed to the array memory re-allocation may happen, invalidating the reference `e` to element index 0.

### 2.2 Viewer and other Windows

To be completed.

## 3 Frequently Asked Questions

SIG was developed over several years according to the needs of a number of projects it has supported in different platforms. It provides an integrated framework that is efficient and very flexible.

### 3.1 Why not update SIG to use std templates?

Besides the restructuring that would be needed, too much code bloat would be included. For example, when just the header files of ostream, istream, and vector are included in gs.h the compilation time of SIG more than doubles. Also, it is difficult to customize these classes to a variety of needs. For example arrays adopting memory from other arrays, input with built-in parsing utilities, redirection to/from generic functions, etc. For these reasons, SIG will remain independent of std templates.

### 3.2 My project is not compiling, what could be wrong?

First of all, make sure the same Visual Studio configurations are being compiled for the libraries and for your program. For example, select configuration "Release" everywhere, or configuration "Debug" everywhere, or configuration "ReleaseDLL" everywhere. If you are starting from `sigapp`, also make sure that SIG and your project are under the same parent folder.

### 3.3 Will the included projects work if I use a different version of Visual Studio?

In most cases yes. It may help to edit the project files and change version numbers to match your version of Visual Studio, and many times you will need to retarget the projects to the Microsoft SDK version that you are trying to use.

### 3.4 Mouse events are not matching with the graphics output, what could be wrong?

Before anything else, make sure the drivers of your graphics card are up to date. SIG needs OpenGL 4 support and drivers fully up to date.

## References

- [1] M. Kallmann. Analytical inverse kinematics with body posture control. *Computer Animation and Virtual Worlds*, 19(2):79–91, 2008.

## A Description of SIG Data Files

The following simple notation is used to specify the format of text data files used in SIG.

- Single letters, such as *i* or *x* denote that a number is expected. The chosen letters should help identify the meaning of the numbers, for example, *i* denotes integers while *x* a real number coordinate. Indices may be used in the following way: *i1*, *i2*, and double letters such as *nm* meaning “number of materials” may also be used.
- Keywords are any names that are not single or double-letter strings.
- Parameters are any names appearing between `< >`, indicating that a name or number is expected as a parameter.
- Optional commands will appear inside brackets, such that the entire section inside the brackets is optional. For example, command `[name <name>]` indicates that specifying a name is optional.
- Delimiter “|” separates a list of keywords or numbers where only one element of the list is to be chosen as a parameter.

This simple description is enough to describe the used data files, which are specified in the next sections.

## A.1 GsModel .m Model Definition File

(Status: needs revision with respect to the new GSModel internal format including grouped information.

```
GsModel          # signature to identify the file

[name <name> ]   # if not given, name becomes an empty string

[culling <0|1>]  # if not defined, back-face culling is on by default

vertices <nv>    # list of vertices is mandatory, nv is the number of vertices
<x> <y> <z>
...

faces <nf>       # list of triangular faces is mandatory
<a> <b> <c>       # a triangle is defined with indices to the vertex list, starting from 0
...

[normals <nm>    # optional list of normals per vertex
<x> <y> <z>
...]

[fnormals <nf>   # optional list of normals per face
<a> <b> <c>
...]

[materials <nm>   # list of materials, each material is read by GsMaterial input operator
amb <r> <g> <b> <a> dif <r> <g> <b> <a> spe <r> <g> <b> <a> emi <r> <g> <b> <a> shi <v> [tid <i>]
...]

[fmaterials <mf> # indices of materials to be assigned per face
<i1>
<i2>
...]

[mtlnames        # optional names for each material index
i name1
i name2
...]

[textcoords <nt> # texture coordinates defined per vertex
<u> <v>
...]

[textures <nt>
<image.png>      # image file for each texture to be used
...]

[ftextcoords <nf> # texture coordinates as indices per face
<a> <b> <c>
...
<a> <b> <c>]

[primitive       # if the model represents a primitive, the primitive parameters go here
<box|sphere|cylinder|capsule> <ra> [rb] [rc] <nfaces> #(nfaces needed even for a box)
[center <x y z>]
[orientation axis <x y z> ang <deg>]
[material amb <r> <g> <b> <a> dif <r> <g> <b> <a> spe <r> <g> <b> <a> emi <r> <g> <b> <a> shi <v>]
[color <r> <g> <b> <a>] # color will set the diffuse color of the default material
[smooth|flat]
;
]
```



## A.2 KnSkeleton .s Skeleton Definition File

```
KnSkeleton          # Signature. It should be the first keyword of the file.

[ path|add_path <path> ] # Loaded geometry files will be searched in the
                        # same directory of the .s file, or also searched
                        # in the directories specified with the path command.
                        # Several paths can be defined to be searched.

[ name|set_name <skelname> ] # Specifies the name of the skeleton

[ scale <scale factor> ] # Command scale is used to scale the length of the
                        # skeleton links (offsets), for example for converting
                        # units. Translational limits are also scaled.

[ globalgeo <true|false> ] # If true, the geometry is considered to be loaded in
                        # global coordinates and therefore all geometries are
                        # converted to local coordinates after loaded.
                        # By default globalgeo is considered false.

<SKELETON_DEFINITION> # Usually the skeleton definition comes here. The
                        # definition syntax is specified later on in this file.

[ posture <name val1 val2 ... valN> ] # Command posture specifies a posture which
                        # values must match the active channels of the
                        # skeleton. All loaded postures will share the
                        # same channels. This command must come after the
                        # skeleton definition.

[ dist_func_joints <joint1 joint2 ... jointN;>] # This command specifies which
                        # joints are used in the distance function between
                        # postures. This command must come after all posture
                        # definitions.

[ collision_free_pairs <jointname1 jointname2 ...>; ] # List of joint pairs to
                        # to be deactivated for collision detection.

[ userdata <var1=val; var2=val1 val2; ... varN=val;> ] # This command allows the
                        # specification of any kind of user-related data.
                        # The data is loaded as a GsVars object that is
                        # maintained by the skeleton

[ ik <LeftArm|RightArm|LeftLeg|RightLeg> <jointname> ] # initialize IK with given
                                                # joint as end effector

[ end ] # Optional keyword that forces end of parsing

#### SKELETON_DEFINITION ####
# A skeleton can be defined in two ways: hierarchical or flat.
# The syntax of a hierarchical skeleton definition is:

skeleton # tells this is a hierarchical definition
root <name> # specifies the root joint and its name
{ <JOINTDEFS> # joint definitions go here
  joint <name> # specifies child joint and name
  { <JOINTDEFS> # etc
    joint <name>
    { ...
    }
  }
  ...
}
```

```

# The syntax of a flat non-hierarchical skeleton definition is:

root <name>                                # first specify the root joint
{ <JOINTDEFS>
}
joint <name> : <parent name> # then specify each joint with its name and its
{ <JOINTDEFS>                # parent's name, which must be previously defined
}
...                            # etc

# It is possible to modify the settings of a previously defined joint with
# the following syntax (the syntax of a .sd file):
joint <name>
{ (JOINTDEFS)
}

#### JOINTDEFS ####
# The possible joint definitions are listed below.
# Rotations specified in "axis <x y z> ang <a>" can also be written as "x y z a",
# where a is an angle in degrees.

[offset|center <x y z> ]

[euler XYZ|YXZ|YZX|ZY]

[channel XPos|YPos|ZPos|XRot|YRot|ZRot <val> [free | <min><max> | lim <min><max>] ]

[channel Quat [axis <x> <y> <z> ang <degrees>] [frozen] ]

[channel Swing [axis <x> <y> ang <degrees>] [lim <xradius> <yradius>] ]

[channel Twist <val> [free | <min><max> | lim <min><max>] ]

[modelmat <4x4matrix as 16 floats>]          # apply to the joint model

[modelrot <axis <x> <y> <z> ang <degrees>>]  # apply to the joint model

[prerot <axis <x> <y> <z> ang <degrees>>]    # joint pre rotation

[postrot <axis <x> <y> <z> ang <degrees>>]    # joint post rotation

[align <pre|post|prepost|preinv> <x y z>]    # set pre/post for aligning given vector

[visgeo <model filename>] # models are "added" if more than one visgeo is declared

[colgeo <model filename>] # models are "added" if more than one colgeo is declared

[visgeo|colgeo primitive <defs>] # see Note 2 below

[visgeo|colgeo shared]    # reuse the other col/visgeo previously defined in the joint

#### Advanced Notes ####
- Note1: Quaternion rotations can now be also loaded with format: xzy <x> <y> <z>
- Note2: Geometries can now also be created with [visgeo|colgeo primitive <defs>;],
        where <defs> are the commands in the primitive description of the .m format

```

### A.3 KnSkeleton .sd Skeleton Data Definition File

```
# The file extension adopted for this file is .sd
# Character '#' is used for comments

KnSkeleton      # Signature. It should be the first keyword of the file

skeldata        # This keyword must come right after the signature
                # for defining that this is not a new skeleton but
                # modifications to the current one.

                # At this point, any skeleton command understood by
                # a .s file can be given here and will overwrite
                # previous definitions.

joint <name>     # For joint (re)definitions, first specify the joint name,
{ (JOINTDEFS)   # then any joint definition commands can be used.
}

joint <name>     # Any number of joints can be modified
{ (JOINTDEFS)
}

...

[ end ]         # Optional end keyword forces end of parsing
```

## A.4 KnPosture .sp Posture Definition File

```
# The file extension adopted for this file is .sp
# Character '#' is used for comments
# A Posture file has no signature

[name <name>]      # Give the Posture a name. Even if the keyword name is
                  # omitted the parser will load a string given here as the name.

channels [<N>]      # Specification of channels start. Parameter N is the number of channels,
                  # then each channel is defined with a joint name and channel type

<ch1jname> <XPos|YPos|ZPos|XRot|YRot|ZRot|Quat|Swing|Twist>
<ch2jname> <XPos|YPos|ZPos|XRot|YRot|ZRot|Quat|Swing|Twist>
...
<chNjname> <XPos|YPos|ZPos|XRot|YRot|ZRot|Quat|Swing|Twist>

[;]               # The number of channels N may be omitted, and only in that case,
                  # a ';' must be written at the end of the channel list definition

val1 val2 ... valK # the joint values of the Posture must match the channel description:
                  # - channels of types Xpos, YPos, ZPos, XRot, YRot, ZRot require one value each,
                  # - channel Quat is described by 3 values, which are the axis-angle description
                  #   of the quaternion rotation,
                  # - channel Swing requires 2 values, the 2D axis-angle of the swing rotation,
                  # - channel Twist requires 1 angle value.
                  # - All angles are to be specified in degrees.
```

## A.5 KnMotion .sm Motion Definition File

```
#
# .sm skeleton motion file Description
#

KnMotion                                # signature

[ name <namestring> ]                  # specifies a name for the motion (optional but recommended)

channels <N>                            # channels are defined in the same way as for posture definitions
<ch1jname> <ch1type>                   # see .sp file documentation for a detailed description
<ch2jname> <ch2type>
...
<chNjname> <chNtype>

[ startkt|start_kt <keytime> ]         # optional command to adjust keytimes to start with given value

[ frames <numframes> ]                 # optionally gives how many frames are in this motion
                                        # if not specified, will parse until the end of the file

kt <keytime> fr <POSTVALUES>           # frame data, where POSTVALUES is written according to the .sp format,
kt <keytime> fr <POSTVALUES>           # which follows the channels description
...
```