# Berkeley UNIGRAFIX 3.1 — Data Structure and Language


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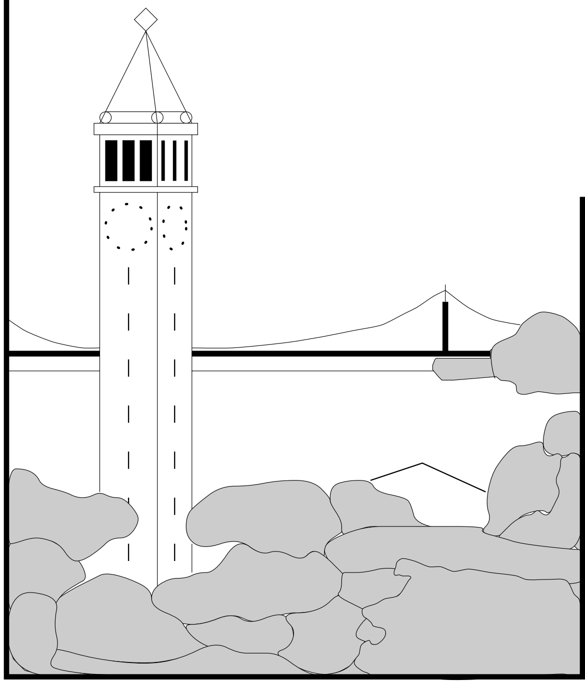


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# Berkeley UNIGRAFIX 3.1 — Data Structure and Language

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*ABSTRACT*

This report describes version 3.1 of the Berkeley UNIGRAFIX scene description language and associated C language data structure and library, libug. The library provides support for reading and writing of scenes, calculating various properties (such as the bounding box of a definition), manipulating geometry and topology, and various other bookkeeping operations. Maintaining the language parser along with the other subroutines means that programs linking with the library will recognize the whole language. In particular, nested definitions and hierarchical references, which are difficult to implement correctly, are essentially free. All previously undocumented features of UNIGRAFIX 3.0 are documented, as well as the new features incorporated from the Soda Hall walkthrough project.

## 1. Introduction

The UNIGRAFIX language is a concise textual scene description language intended for the manipulation and interchange of 3-dimensional polyhedra. In addition to polyhedra, non-manifold objects such as disjoint planar faces with arbitrary holes (the building blocks of polyhedra), and piecewise linear lines (wires) can be described. The textual format was originally chosen for its simplicity, ease of debugging, and portability. In the past, each programmer implemented his own parser to convert from the textual format to an internal data structure. In this report, we describe an application programmer interface (API) for a UNIGRAFIX binary data structure, otherwise known as the *ug* library or *libug*. The *ug* library provides cross-application consistency for archiving and retrieval of scene data, as well as for the API. By using the *ug* library, an application automatically tracks changes to the language, and the subroutines that manipulate the data structure can be shared between programmers.

The data structure design and implementation is the work of Michael Natkin† and Greg Couch. The version described herein contains subsequent additions and modifications by Eric Enderton, Kevin Smith, and Greg Couch.

The UNIGRAFIX language described in [Séquin90] is a subset of what the parser actually recognized and the data structure supported. For example, nested definitions were already supported at the time of the previous report. This version of the language, henceforth know as version 3.1, also incorporates language modifications that were made to support the Soda Hall walkthrough project [Funkhouser92]. Because of those changes, the direct correspondence of elements of the data structure to the language, and the desire to minimize the number of documents needed to learn the UNIGRAFIX language, a detailed description follows that incorporates parts of the previous description [Séquin84]. Section 2 describes the UNIGRAFIX language, and section 3 describes the data structure and library.

† Michael Natkin worked for Professor Séquin at U.C. Berkeley from February through April of 1987.

## 2. The UNIGRAFIX Language Elements

The following is a description of each statement type in the UNIGRAFIX language. Statements can be loosely categorized into five categories: geometry (vertices), topology (faces, wires), hierarchy (definitions, instances, arrays), rendering information (material properties, textures, lights, cameras), and other (include, execute, C preprocessor, comments, extension). As a convenience for past users, the differences from the previous description, version 3.0, are highlighted with a sidebar along the right margin. The synopsis of changes include: 1) color has been generalized to material properties, 2) hierarchical references to vertices are allowed, 3) there are more transformation types, and 4) a statement extension mechanism has been implemented.

For completeness, the UNICUBIX[Shirman90] extensions for nameable edges, borders, and patches are described here even though they have yet not been incorporated into the ug library yet.

### 2.1. Syntax

- A UNIGRAFIX scene description consists of a sequence of statements, each starting with a keyword and ending with a semicolon. The exception to this rule is extension statements which are enclosed within parenthesis.
- Identifiers consist of letters, digits, underscore, sharp sign, and colons. They must not start with a digit, and case is significant.
- Identifiers are unique within each statement type.
- All literal text is in **boldface**, text that must be substituted is in *italic*. Square brackets ([]) denote optional fields, and three periods (...) denote optional repetition of the preceding identifier or grouping.
- All numbers are real, *i.e.*, digits optionally followed by fractional part (decimal point and digits) optionally followed by an exponent (an E, a plus or minus sign, and digits) — the leading digits are optional if there is a fractional part.
- White space is used to separate tokens that would be otherwise unseparable.

### 2.2. Vertex Statement

Usage: **v** *ID x y z* [*w*] [*materialID*]**;**

All object coordinates in UNIGRAFIX appear in vertex statements. The *ID*entifier uniquely identifies the vertex within a scene or definition. *x*, *y*, and *z* are the 3-dimensional coordinates of the vertex. The homogeneous coordinate, *w*, may be given as well. The optional *materialID*entifier selects the material properties of the vertex. Vertices must be specified before they are referenced. Vertices can be referred to hierarchically through instance chains. See the description of the instance and array statements for examples of hierarchical references to vertices.

Examples of vertices are:

```
v origin 0 0 0;
v upper_right 3.5 10 3.4e2;
```

### 2.3. Wire Statement

Usage: **w** [*ID*] **(***vertex1 ... vertexN***)** ... [*materialID*]**;**

The wire statement describes piecewise linear lines. Each group of vertices must have at least two elements. The *materialID*entifier selects the material properties of the wire.

Examples of wires are:

```
w bristle (v34 v94) brown;
w closed_loop (v1 v2 v3 v4 v5 v6 v7 v1);
w (origin instance.upper_right);
w tetra (lt rt top back) (rt back lt top) red;
```

The last example creates a *red* wire frame of a tetrahedron.

### 2.4. Edge Statements

Usage: **el** [*id*] **(***vertex1 vertex2***);**
Usage: **ec** [*id*] **(***vertex1 vertex2 x1 y1 z1 x2 y2 z2***);**

The curved edge, differs from the linear edge, by specifying the two interior control points, (x1, y1, z1) and (x2, y2, z2), of a cubic bezier curve. Typically, a surface is discontinuous at an edge. *Not implemented yet.*

### 2.5. Border Statements

Usage: **bl** [*id*] **(***vertex1 vertex2***);**
Usage: **bc** [*id*] **(***vertex1 vertex2 x1 y1 z1 x2 y2 z2***);**

Borders are edges where the tangent vector across the edge must be continuous. The linear border, is analogous to the linear edge, and the curved border, is analogous to the curved edge. *Not implemented yet.*

### 2.6. Face Statement

Usage: **f** [*ID*] **(***vertex1 vertex2 ... vertexN***)** ... [*materialID*]**;**

The face statement describes a planar polygon that may have holes. The first vertex group must have at least three elements and the outer side of the face is determined by their counter-clockwise order. Each vertex group is automatically closed. The *materialID*entifier selects the material properties of the face. Any additional vertex groups describe holes in the face and may be degenerate (*i.e.*, one or two vertices). The vertices of holes must be given in clockwise order, holes of holes (*i.e.*, ‘‘islands’’) in counter-clockwise order, *etc.*.

Examples of face statements are:

```
f square (ll lr ur ul);
f holey_triangle (c1 c2 c3) (h1 h3 h2);
```

### 2.7. Patch Statement

Usage: **p** [*ID*] **(***vertex1 vertex2 vertex3* [*vertex4*]**)** [*materialID*]**;**

The patch statement describes either a triangular or a quadrilateral patch. *Not implemented yet.*

### 2.8. Definition statement

Usage: **def** *ID* [**solid**]**;** *arbitrary-UNIGRAFIX-statement ...* **end ;**

Definitions provide a method for abstracting part of a scene for multiple instantiations in different orientations and materials. The *ID*entifier uniquely identifies the definition within a scene or definition. The **solid** keyword is a hint for renderers, so they may cull backfaces if the material is opaque. A definition is not visible unless it is instantiated with an instance or array statement.

Definitions provide a scope for identifiers, for example, a vertex could have the same identifier in different definitions. Definitions may be arbitrarily nested. Identifier references to definition and material statements may reference statements in outer nesting levels (with statements in the current definition overriding ones in outer levels), while all other references must be to statements in the current definition.

An example of a definition statement defining a tetrahedron is:

```
def tetra solid;
        v XZ   1 -1  1;
        v YZ  -1  1  1;
        v XY   1  1 -1;
        v N   -1 -1 -1;
        f xyz  (YZ XZ XY);
        f x    (N XY XZ);
        f y    (XY N YZ);
        f z    (XZ YZ N);
end;
```

### 2.9. Instance Statement

Usage: **i** [*ID*] **(***defID* [*materialID* [*lightsID*]] [*xforms*]**);**

The instance statement instantiates the named definition, *defID*entifier, optionally of a given material, *materialID*entifier, optionally just lit by one set of lights, *lightsID*entifier, and optionally transformed to a different position and/or orientation, *xforms*. The possible transformations are listed below. The *ID*entifier is required to make a hierarchical reference to one of the vertices instantiated. Hierarchical references to vertices through instances are formed by prefixing the vertex identifier with the instance identifier and a period.

Examples of instance statements and hierarchical vertex references are:

```
i red_tetra (tetra red -tv 10 -5 20 1.0);
i (tetra) -sa 5;
w (red_tetra.N origin);
```

### 2.10. Array Statement

Usage: **a** [*ID*] **(***defID* [*materialID* [*lightsID*]] [*xforms*]**)** *count* [*incremental-xforms*]**;**

The array statement instantiates the named definition, *defID*entifier, *count* times, optionally of a given material, *materialID*entifier, optionally just lit by one set of lights, *lightsID*entifier, and optionally with an initial transformation list, *xforms*, and incremental transformations list, *incremental-xforms*. The transformations are listed below. The *ID*entifier is required to make a hierarchical reference to one of the vertices instantiated. Hierarchical references to vertices through arrays are formed by prefixing the vertex identifier with the array identifier, a colon, an integer subscript, and a period. Subscripts start from zero.

Examples of array statements and hierarchical vertex references are:

```
a rt (tetra red -tx 10) 5 -sa 0.75;
w (origin rt:2.N) (rt:0.XY rt:4.YZ);
```

### 2.11. Transformations

Transformations in instance and array statements start with a dash and a two letter code and may be followed by zero to sixteen parameters as needed. The first letter is a **s** for scaling, a **t** translation, a **r** rotation, a **m** mirroring, or a **M** for an explicit matrix. The second letter is a **x** for the X-axis, a **y** for the Y-axis, a **z**z for the Z-axis, an **a** for all axes, a **v** for an arbitrary vector, a **3** for a 3 by 3 matrix, or a **4** for a 4 by 4 matrix. Mirroring reorders the vertices in faces to preserve outside-ness. Mirroring is always about a plane through the origin, and the axis or vector is normal to that plane. Angles are in degrees.

All of the legal combinations are given below:

**-sx** *scale_factor*
**-sy** *scale_factor*
**-sz** *scale_factor*
**-sa** *scale_factor*
**-sv** *x y z scale_factor*
**-tx** *translation_amount*
**-ty** *translation_amount*
**-tz** *translation_amount*
**-ta** *xyz_amount*
**-tv** *x y z amount*
**-rx** *angle*
**-ry** *angle*
**-rz** *angle*
**-rv** *x y z angle*
**-mx**
**-my**
**-mz**
**-ma**
**-mv** *x y z*
**-M3** $a_{00}$ $a_{01}$ $a_{02}$ $a_{20}$ $a_{11}$ $a_{12}$ $a_{20}$ $a_{21}$ $a_{22}$
**-M4** $a_{00}$ $a_{01}$ $a_{02}$ $a_{03}$ $a_{10}$ $a_{11}$ $a_{12}$ $a_{13}$ $a_{20}$ $a_{21}$ $a_{22}$ $a_{23}$ $a_{30}$ $a_{31}$ $a_{32}$ $a_{33}$

### 2.12. Color Statements

Usage: **c**[**olor**] *ID lightness* [*hue* [*saturation* [*translucency*]]]**;**
Usage: **c**[**olor**]**_rgb** *ID red green blue* [*translucency*] [*textureID*]**;**

The color statement is a shorthand for material definition that sets both the ambient color and the diffuse color to the given color value. See the sections on materials below for a description of the various arguments. The *ID*entifier shares the same namespace as that of the material definition statement identifiers.

### 2.13. Material Definition Statement

Usage: **defmat** *ID***;** *material-statement ...* **end ;**

A material definition may only contain material statements; they are listed in the following section. The *ID*entifier provides a unique reference to the material.

#### 2.13.1. Material Statements

Usage: **c**[**olor**] *lightness* [*hue* [*saturation*]]**;**
Usage: **c**[**olor**]**_rgb** *red green blue***;**
Usage: **emission** *lightness* [*hue* [*saturation*]]**;**
Usage: **emission_rgb** *red green blue***;**
Usage: **ambient** *lightness* [*hue* [*saturation*]]**;**
Usage: **ambient_rgb** *red green blue***;**
Usage: **diffuse** *lightness* [*hue* [*saturation*]]**;**
Usage: **diffuse_rgb** *red green blue***;**
Usage: **specular** *lightness* [*hue* [*saturation*]]**;**
Usage: **specular_rgb** *red green blue***;**
Usage: **shininess** *exponent***;**
Usage: **opacity** *translucency***;**
Usage: **texture** *textureID***;**

Materials have four color components, emission, ambient, diffuse, specular, a specular shininess, an opacity/translucency, and an associated texture. Each of the color components can be specified with either the RGB color model or the HLS color model [Foley90]. In the RGB (**_rgb** suffix) versions of the material statements, *red*, *green*, and *blue* should all range from zero to one. The HLS versions of the material statements uses a double cone color model; *lightness* should fall in the range from zero (black) to one (white) with saturated colors having a lightness value of one half; *hue* should be a number between zero and 360, and follows a standard color wheel: red (0), yellow (60), green (120), cyan (180), blue (240), magenta (300); *saturation* should fall in the range from zero (gray-scale) to one (fully saturated). The default *hue* and *saturation* are undefined (gray), and fully saturated, respectively.

The specular shininess *exponent* defaults to zero (off) and is the same as the exponent in the Phong lighting model [Bui-Toung75].

*Translucency* ranges from zero (opaque) to one (translucent) and is used by some renderers to implement semi-transparent objects. By default, all materials are opaque.

The *textureID*entifier is a reference to a texture (defined below).

### 2.14. Texture Definition Statement

Usage: **deftex** *ID***;** *texture-statement* ... **end ;**

A texture definition may only contain texture statements that are listed in the following section. The *ID*entifier provides a unique reference to the texture.

### 2.15. Texture Statements

Usage: **t_file** *filename***;**
Usage: **t_type** *type***;**
Usage: **t_size** *width height num-components***;**
Usage: **t_wrap** *style***;**
Usage: **t_filter** *min-filter mag-filter***;**
Usage: **t_scale** *u-scale v-scale***;**

The texture statements may appear at most once and in any order inside a texture definition. The texture statements correspond to the information needed for an OpenGL renderer, see [Neider93] for a more detailed description. The **t_file** and **t_size** statements are required. The *filename* is the name of the file that contains the texture. The *type* is an integer that gives the texture file format, *i.e.* 0 for an SGI image file format, and 1 for the tiff format (unsupported). Each pixel in the texture file corresponds to a texel in the texture. The *width*, *height*, and *num-components* fields give the width in texels, height in texels, and the number of components in the texture. A 1 component texture file is used as an intensity map; a 2 component file is used as an intensity-alpha map, a 3 component file is used as RGB map, and 4 component file is used as a RGBA map. The *min-filter* specifies which filter to use when more than one texel of the texture corresponds to a pixel on the screen (minification): 0 is a point filter, 1 is a bilinear filter, 2 is a select a point from a precomputed filter, 3 is a linear filter using precomputed filters, 4 is a bilinear filter using precomputed filters, and 5 is a mipmap trilinear filter using precompute filters. The *mag-filter* specifies which filter to use when one texel of the texture corresponds to more than one pixel on the screen (magnify): 0 is a point filter, and 1 is a bilinear filter. The *style* tells how the texture behaves at its boundarys, 0 if it repeats (default), and 1 if it clamps. The *u-scale* and *v-scale* tell the number of times to replicate the texture within the selected face if the *style* is set to repeat, in the u and v directions respectively.

### 2.16. Light Definition Statement

Usage: **deflights** *ID***;** *light-statement* ... **end ;**

A lights definition may only contain light statements that are listed in the following section. The *ID*entifier provides a unique reference to the set of lights.

### 2.17. Light Statement

Usage: **l** *intensity* [*x y z* [*w*]] [*materialID*]**;**

The light statement places a light source in the scene. The *intensity* specifies the brightness of the light source. The *materialID*entifier selects a material that colors the light for smarter renderers (the default is to use only the *intensity* and ignore a light's color). The light source defaults to be an ambient light source unless *x*, *y*, and *z* are given in which case it is a directional light with *x*, *y*, and *z* being the directional vector (it need not be normalized). If *w* is given and non-zero, then it is a point light source.

### 2.18. Camera Statement

Usage: **cam** [*ID*] *viewing-option ...* **;**

The camera statement places a camera in the scene. A renderer will default to using the last camera statement in a scene unless a camera identifier is given as an argument. If no camera statement is present in a scene, an implicit camera is created that views all elements in the scene.
The many *viewing-option*s are:

| Projection style | |
|---|---|
| **–og** | set orthographic mode (the default) |
| **–ps** | set perspective mode |
| World to Eye Coordinates | |
| **–vc** *x y z* | set the view center (the look at point) |
| **–ep** *x y z* | set the eye point (the look from point) |
| **–ud** *x y z* | set the up direction (not a point). |

| Eye Coordinates to Canonical View Volume (Only two of the **–va**, **–fs**, and **–fl** need be present to fully specify the eye to canonical view transformation) | |
|---|---|
| **–va** *x-angle y-angle* | set the viewing angles |
| **–fs** *x-size y-size* | set the film size |
| **–fl** *length* | set the focal length |
| **–cl** *hither yon* | set the hither and yon clipping planes (in view volume coordinates) |
| **–ph** *left right bottom top* | set the porthole in the viewport to render (expressed in normalized device coordinates, -1.0 to 1.0 inclusive) |

### 2.19. Include Statement

Usage: **include** *filename***;**

The include statement allows the creation of libraries of scene elements. The text in the given *filename* incorporated into the scene at the current location. If the *filename* is an absolute path (starts with a slash, /), or starts with a tilde, ˜, then it is read from the given location. Otherwise the UGMODELPATH environment variable is consulted for a list of directories (colon separated) in which to look for the file. If the UGMODELPATH environment variable is not set, then only the current directory is checked.

### 2.20. Execute Statement

Usage: **execute** *UNIX-command***;**

The execute statement causes the textual output from the given *UNIX command* to be incorporated into the scene at the current location. The PATH environment variable is consulted for a list of directories (colon separated) to look in for the given program.

### 2.21. C Preprocessor Support

Usage: **#** *line-number quoted-filename*

A line beginning with a **#** denotes a C preprocessor synchronizing line for supporting error messaging in the presence of **#include** directives. See the UNIX manual page for *cpp*.

## 2.22. Comments

Usage: **{** *anything — { nesting is OK }* **}**

Comments may be placed anywhere that white space may occur. This includes almost any possible place except within identifiers or numbers. Comments are surrounded by curly braces, **{** and **}**, and may contain any character as long as curly braces are balanced. For example:

```
{ This is a legal comment }
{ This is also a { more complicated } legal
        { using nested {}'s } comment }
```

## 2.23. Extension (Escape) Statement

Usage: **(***anything with balanced parenthesis***)**

Extension statements are provided as a mechanism for preprocessors to augment scene descriptions, such as the BUMP [Oakland87] animation package.

## 3. The UG Library — UNIGRAFIX Data Structure and Subroutines

Libug, is a collection of subroutines for manipulating those polygonal models that can be described with the UNIGRAFIX language. The library provides support for reading and writing of the textual format, calculating various properties (such as the bounding box of a definition), manipulating geometry and topology, and various other bookkeeping operations. Elements of the data structure have a one-to-one correspondence to elements of the UNIGRAFIX language, such as statements, transformations, *etc.*. Maintaining the language parser along with the other subroutines means that programs linking with the library will recognize the whole language. In particular, nested definitions and hierarchical references, which are difficult to implement correctly, are essentially free.

Details of the API can be found in the manual page reproduced in an appendix. In the following sections, we will discuss the major design decisions, explain how the more difficult features were implemented, and say what should have been done differently.

### 3.1. Implementation Language

The ug library was written in a style in C that generously may be called object-oriented. All data are contained within objects (C structures), all accesses to the instance data (structure fields) is through macros, there are common messages (functions) that work on a variety of object types, and one level of inheritance is used to factor out the common code for handling each UNIGRAFIX statement type. A decomposition of the code within the library, would naturally separate the code on object-oriented boundaries, and would cleanly map into an object-oriented language. If C++ had been more mature when the ug library was written, it would have been a much better implementation language. The reason for taking the pseudo-object-oriented approach was to isolate implementation details from the interface, and it has successfully done so.

### 3.2. Data Structure

This UNIGRAFIX data structure is similar to the standard winged-edge data structure [Hanrahan82] but differs in many important ways. A winged-edge data structure describes a single closed shape and requires that an edge have at most two faces connected to it. UNIGRAFIX can describe non-manifold structures such as multiple closed shapes sharing vertices, edges, and faces. For example, in UNIGRAFIX a fan of rectangles that share a common edge, will also share that edge in the data structure. And in UNIGRAFIX, faces may have holes (contours) in them, while in a winged-edge data structure they may not. The contours make algorithms written for the UNIGRAFIX data structure slightly more complicated than ones written for a winged-edge data structure which is a trade-off for the greater expressive power of the UNIGRAFIX data structure.

Figure 1 shows the data structure for an uncolored square that is generated by the following UNIGRAFIX statements:

```
v v1 0 0 0;
v v2 1 0 0;
v v3 1 1 0;
v v4 0 1 0;
f square (v1 v2 v3 v4);
```

For the *square* polygonal face, we have a list of all of the face's contours, each contour has a list of edge directions and edges, and each edge has a list of vertices (always two). Also each of the above types has a list of all references to it — vertices have a list of edges to which they belong, edges have a list of contours, and contours have an associated face. Since edges are shared between faces, it works well to have them be another statement type (and it will help when adding UNICUBIX extensions). Since contours are not shared, the only advantage of having them be a separate statement is to share implementation code. (Contours might conceivably be shared among the curved patches from UNICUBIX, but it probably only would be useful for border contours.)

Missing from figure 1 are the links between statements of the same type. All statements of the same type in a definition or scene are connected in a doubly linked list. Being able to visit all statements in a particular order is important when writing the data structure to a text file because identifiers need to be defined before they are referenced. It is also important for flattening instance hierarchies (see section

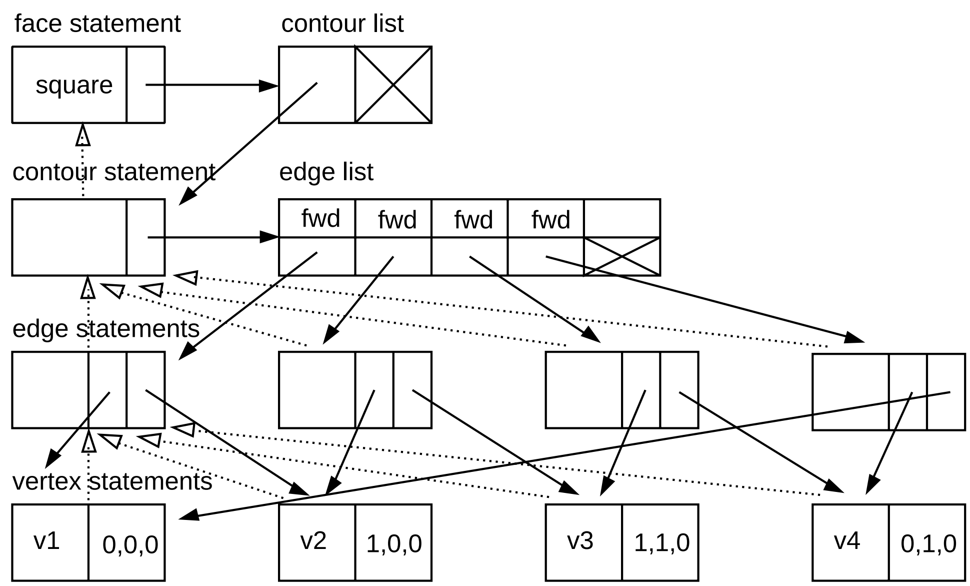


Figure 1 — simple square face

below on flattening).

### 3.3. Hierarchical References to Vertices

Usually an edge points directly to its associated vertices. When there is a hierarchical reference to a vertex, the vertex statement is replaced by a shadow statement. Conceptually, the shadow statement pretends it is the actual vertex and then uses the instantiation path to return modified coordinate and normal values. Transforming the shadowed vertex information is computationally expensive in comparison to just copying the coordinate or normal values, but it is sometimes the best way to describe linkages between instances.

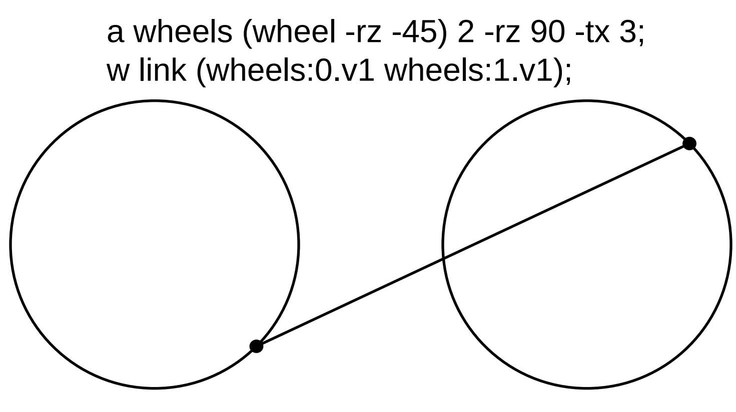


Figure 2 — train wheels

Figure 2 demonstrates why hierarchical references are useful with a train wheel example. The two wheels are linked with a wire that makes hierarchical references to a vertex in each wheel.

### 3.4. Expanding Instances — Flattening a Scene

The flattening algorithm is heavily dependent upon a partial ordering of the UNIGRAFIX statement types in the ug library. The partial ordering is derived from the graph expressing which statement types make references to other statement types. Statements that are referred to need to be flattened first. If a new statement type is introduced, it needs to placed in the correct order relative the other statement types. The current ordering is as follows: textures, materials, lights, definitions, instances, arrays, shadows, vertices, edges, contours, wires, faces, cameras, and extensions. When the UNICUBIX statement types are incorporated, the edge and border types will be either immediately before or after edges, and patches will be either immediately before or after faces.

Shadow statements are used as place holders for hierarchical references to vertices. As each instance is expanded, the hierarchical name of the instance is cached. A vertex has a flag stating whether or not it is shadowed. When a shadowed vertex is transformed, all of the shadow statements that refer to it are examined to see if the name used to refer to the vertex matches the current hierarchical name (*i.e.* if the shadow statement's name is a suffix of the current hierarchical name). This handles multiple hierarchical references through multiple levels of instantiation. There is a computational cost of maintaining the current hierarchical name which is wasteful in scenes that don't have any hierarchical references. Luckily, the overhead is fairly low and is proportional to the instance tree complexity of scene, which should be at least an order of magnitue smaller than the number of primitives duplicated (vertices, edges, wires, faces, *etc.*).

### 3.5. Nested Definitions

Each definition has its own lexical scope and is assigned a unique lexical level number, an LLN. A LLN is never reused during a program. An explicit list of visible LLN's is maintained while parsing the UNIGRAFIX language to track in which scopes an identifier might be found. Local identifiers override identifiers with the same name in outer scopes. How LLN's work to improve symbol table performance is described in [Cook83]. The application programmer rarely uses the fact that there is a full symbol table available, as most applications implicitly work with scene descriptions that have no definitions in them (*i.e.* flat scenes). One exception is the bump animation package [Oakland87] which uses scoped language extensions to implement its features.

There is one implementation detail in the hash table used for the symbol table code that needs explaining. By design, the hash table uses the linked-list chaining method to reduce lookup time for symbols while parsing. The **UG_symbol** structure is the linked-list element that is used to maintain the chain, and the UGstmt structure points back to the UG_symbol in the hash chain that references the UGstmt. The back pointer is used to remove the entry from the symbol table when a named statement is deleted. Because the hash chain is a singly linked list, the UG_symbol is never reclaimed, thus causing a small memory leak each time a named statement is deleted. Should this be a problem, it will be possible to reclaim the space the next time that hash chain is searched.

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## NAME

ug — manipulate UNIGRAFIX data structures

## SYNOPSIS

#include <ug.h>

cc -I${UGHOME}/include ... -L${UGHOME}/lib -lug -lmat -lcompat

## DESCRIPTION

This is a specification for the UG package, which implements all manipulations of the internal UNIGRAFIX data structures, and the transfer of those data structures to and from text files. The grammar of the language can be found in a related document *ug*(5). Several sample programs are in src/packages/ug/examples. A file with fragments showing how to wind around in the topology statements is examples/refer. Probably the best way to become familiar with this packages is to have a quick read through this manual, including the macro section at the end, then look over the sample programs and possibly modify them to gain some familiarity with the data structures.

In the context of this package, a statement is the fundamental object in the data structure. In many cases there is a one to one correspondence between lines in the UNIGRAFIX file and statements in the ug data structures, but this is notably not true for the topology statements, as there are intermediate statement types representing edges and contours which do not appear in the text files. Conceptually, the user of this package should think of the data structure as an ordered, branching, doubly-linked list of statements, and a statement as a sort of variant record which may contain a light, a vertex, etc. To see what data is in the variant part of each statement, look at the macro listings at the end of the manual. It is also possible to loop through all of the statements of any one type in a file.

All references between statements are mediated through reference lists. Every statement has a TO list, which contains pointers to all statements which refer to it, and a FROM list which contains pointers to all statements to which it refers. FROM lists always contain at least one entry, which is a pointer to a NULL statement, for example, a face with no color will have it's FACE_COLOR index set to refer to the NULL reference in it's FROM list.

Statments in text files which begin with a "(" are read verbatim into a UG_ESCAPE_STMT until the matching ")" is found. See UGset_escape_routine.

Hierarchical references from one statement to another are allowed and are kept in *shadow* statements (See UGfind_reference, UGfind_vertex_coords). This is currently used only for vertices, but should be usable for other types. The routines here hide the fact that there are shadow statements fairly well, but one must be aware of them.

## I/O ROUTINES

**UGfile ***
**UGread(UGfile *uf, FILE *fp, const char *filename, int first_line)**

**UGfile ***
**UGread_str(UGfile *uf, char *str, const char *filename, int first_line)**

**UGfile ***
**UGread_lls(UGfile *uf, FILE *fp, int *lln_list, int lln_cnt, const char *filename, int first_line)**

**UGfile ***
**UGread_str_lls(UGfile *uf, char *tr, int *lln_list, int lln_cnt, const char *filename, int first_line)**

These functions read a scene from either the file pointer **fp** or the string **str**, and build the internal data structure (a UGfile) that represents it. This representation is sufficient to allow the file to be written back in nearly identical form to the original, depending on the changes made by the calling program. If the parameter **uf** equals NULL, a structure is allocated and returned as the value of the function. Otherwise, the new UGstmt's are appended. NULL is returned on errors.

The filename and first_line arguments are for setting the initial values used for error messages.

If a statement being read needs to refer to objects defined outside of **uf** — *e.g.* if you are reading the inside of a definition, and the statement refers to colors (or definitions) outside the definition's scope — then you need to use UGread_lls (or UGread_str_lls) to provide the parser with a lexical level number stack for UGfind_reference. See UGfind_reference, below.

Files included via UNIGRAFIX's *include* mechanism are found by looking in the directories in the **UGMODELPATH** environment variable.

**FILE ∗**
**UGmodel_open(const char ∗filename, const char ∗mode)**

Opens the given filename by looking in each directory in the **UGMODELPATH** environment variable (directories are colon separated). If the environment variable is not set, then only current directory is used. The mode's are the same as fopen(3S). Csh(1)'s ˜ syntax for home directories is understood.

**BOOL**
**UGwrite(UGfile ∗uf, int indent, FILE ∗fp)**

**BOOL**
**UGwrite_stmt(UGstmt ∗us, int indent, FILE ∗fp)**

Writes a file or individual statement to file pointer **fp**. The output file is not closed. If **indent** is greater than or equal to zero, it will be used as the initial indentation level, and every level of nesting will be indented by an additional four characters. If **indent** equals -1, no indentation is done. FALSE is returned on error.

**BOOL (∗**
**UGset_escape_routine(BOOL (∗rp)(UGstmt ∗, UGfile ∗)))(UGstmt ∗, UGfile ∗)**

Got that? When an unrecognized statement is parsed, the routine pointed to by **rp** is called with two parameters: an escape UGstmt and the UGfile that the statement appears in. This may be the UGfile of a definition nested inside the text file being parsed. The default routine will simply add the statement to the file. The return value of this function is the previous function, so that you can daisy chain them. The return value of the escape routine is currently ignored.

**int**
**UGerror_code(void)**

Returns the error code associated with the most recent error. At some point this document will spell out what errors can be returned from what routines, but for now you can look at the list in ug.h and use common sense, or just call UGprint_error and exit.

**void**
**UGprint_error(void)**

Prints a text message on stderr describing the most recent error. Some UG routines supply UGprint_error with an additional string giving details about the error.

## FILE ROUTINES

**UGfile ∗**
**UGnew_file(void)**

Allocates a file. Returns NULL on error.

**UGfile ∗**
**UGcopy_file(UGfile ∗to, UGfile ∗from)**

Makes a brand new, identical copy of **from**. **To** may be NULL, in which case it is allocated and returned as the function value. NULL return on errors.

**BOOL**
**UGdelete_file(UGfile *uf, BOOL safe)**

Recursively delete all statements in **uf**, then **uf**. The caller may set **safe** to TRUE if memory can be freed without doing all of the maintenance to the topology, because it is known that this file is not referred to in other parts of the data structure. **Safe** currently only affects whether memory is freed or not.

**UGfile ***
**UGflatten(UGfile *uf, const char *prefix, BOOL shorten)**

The specified file **uf** is flattened, and the resulting flat file is returned. **Prefix** is prepended to all generated names and may be blank. If there is no need for the flattened names to be descriptive, pass TRUE for **shorten**, but do use a **prefix** that will avoid collisions. If short names are not used, the output names will be of the form prefix_iname_aname#index_..._name, where iname is an instance name, aname is an array name, and name is the original name of the statement. Flattening is considerably faster with short names. Also note that objects that are referred to by hierarchical referencing will retain their full names, even if **shorten** is TRUE.

## STATEMENT ROUTINES

**UGstmt ***
**UGalloc_stmt(int type)**

Allocates the data structure for a statement of type **type** (defined below). Returns NULL if there are problems.

**BOOL**
**UGadd_stmt(UGstmt *stmt, int loc, UGstmt *ptr, UGfile *uf, BOOL nameok)**

Adds **stmt** to **uf**. If **loc** is UG_BEG or UG_END, **stmt** is put at the beginning or the end of the file, respectively. If **loc** is UG_ARB, **stmt** is placed before the statement pointed to by **ptr**, or if **ptr** is NULL, at the end of the file. The parameter **nameok** may be set to TRUE if it is known that the name of the new statement does not conflict with any other statement in this file, in order to reduce the processing time. FALSE is returned on error.

**UGstmt ***
**UGcopy_stmt_data(UGstmt *to, UGstmt *from)**

Copies all of the data associated with **from** to **to**. The statement name and the reference lists are not copied, but elements of the data which point into the reference list are. **To** may be NULL, in which case it is allocated and returned. Chances are you should be using **UGcopy_file** instead of just the statement data.

**BOOL**
**UGdelete_stmt(UGstmt *stmt, BOOL safe)**

Removes the statement from the data structure, and hopefully does the right thing if this affects the topology of an object. If **safe** is TRUE, then the statement can be freed as well and no maintenance is done to topology because it is known that this statement is not referred to, or because all associated statements will be deleted subsequently. Returns FALSE on error. (Even when **safe** is FALSE, no maintenance is done to topology.)

**BOOL**
**UGfree_stmt(UGstmt *stmt)**

Frees the memory associated with a statement. This should be used to get rid of statments that have never been added to files, but just used independently. In the case of definition statements, the statements inside the UG_DEF_BLOCK are not deleted or freed. Use UGdelete_file for that purpose.

**UGidx**
**UGalloc_ref(UGstmt *from, UGstmt *to)**

Creates a reference handle between the statements. **To** is placed on **from**'s reference FROM list, and vice versa. The UGidx returned is the index in **from**'s FROM list. Thus to make a face red, assuming you have a color statement pointed to by red and a face statement pointed to by face, you would do UG_FACE_COLOR(face) = UGalloc_ref(face, red). To find a face's color statement you would look at UG_REF_FROM(face, UG_FACE_COLOR(face)). To find all of the edges that use a given vertex:

```
UGstmt  *vertex, *edge;
UGidx   i;
for (i = 0; i < UG_STMT_TO_COUNT(vertex); i++) {
        edge = UG_REF_TO(vertex, i);
        if (UG_STMT_TYPE(edge) != UG_EDGE_STMT)
                continue;
        ...
}
```

**UGstmt ***
**UGfind_reference(const char *name, int type, int *lln_list, int lln_cnt, UGfile *where)**

Returns a pointer to the UGstmt that defines the specified **name** of the given **type**. Returns NULL either on error or if the name is not found. **Lln_list** is an array of lexical level numbers in which to look for the statement, and **lln_cnt** is the number of entries in **lln_list**. For most statement types, only the last scope (**lln_list**[**lln_count** - 1]) on the list is searched. For open scope statements (defs, colors, and lights), if there are statements by the same name in several of the scopes in lln_list, the last one is used (*i.e.* the innermost scope). Note that the lln for a UGfile can be obtained using the UG_FILE_LLN macro. Also note that if you are looking in only one scope, say scope x, it is simplest to pass **lln_list** = &x, **lln_cnt** = 1 (You might want to use UGfind_by_name instead — see below).

A **name** may also be prefixed by a series of '.' separated instance and array names. (Arrays must be subscripted with an : followed by an element number). In this case, the scope should be the scope in which the first instance (or array) name is defined. If this is done, a UG_SHADOW_STMT statement will be added to the file **where**. The **where** parameter should therefore point to the UGfile where a reference to the named object will exist. (This parameter may be NULL if you know that there are no periods in the **name**.) This allows flattening to take place properly. The return value from this function will be the pointer to the shadow statement. Shadow statements are skipped by the loop macros available to the applications programmer.

**UGstmt ***
**UGfind_by_name(const char *name, int type, UGfile *uf, MATmatrix mat)**

Returns a pointer to the UGstmt that defines the specified **name** of the give **type**. Returns NULL either on error or if the name is not found. Only looks in the given UGfile, **uf**, and if it is a hierarchical reference, there are no side-effects, *i.e.* it will never return a shadow statement (see UGfind_reference). The resulting pointer is not usable for adding as a reference in the data structure, but is useful for checking for existence and for extracting values. If a non-null value is passed in for the matrix argument, it is filled in with the transformation matrix of the found statement from the given UGfile (*i.e.*, from hierarchical references).

**int**
**UGwalk_inst_hier(UGfile *ugfile, MATmatrix matrix, const UGwalk_funcs *funcs)**

Recursively descends the instance hierarchy starting with the given transformation **matrix**. The **funcs** argument contains callback function pointers for all statement that you are interested in. For each instance the optional push_matrix callback function is called. Then in the statement type order, the setup callback function is called with the current statement, current transformation matrix, whether or not the statement should be mirrored, the current color, the current lights, and the instance path. The instance and array statements are recursively descended after the setup callback function has been called. If a shadowed statement sets its UG_STMT_EXTRA field, then that value is automatically propagated to the UG_STMT_EXTRA field of the appropriate shadow statement. After all of the statements have been visited once, each statement is visited again and the cleanup callback function is called. During cleanup, the UG_STMT_EXTRA field is free'd unless the save_extra flag has been set. The last step is to call the optional pop_matrix callback function.

### STATEMENT SPECIFIC ROUTINES

MATreal *
UGfind_vertex_coords(UGstmt *vertex)

Returns a pointer to the coordinate values of a particular vertex. If the vertex pointer is a shadow (hierarchical reference) then the values returned are the result of transforming the actual vertex coordinates by the concatenation of the transforms of instances in the reference. (See UG_VERT_POINT_SAFE macro.)

**BOOL**
**UGcompute_camera(UGfile *ugfile, UGstmt *cam, float y_over_x)**

Computes the camera matrices represented by the data described in the camera statement. Attempts are made to fill in reasonable default values for viewing options which are not set. For example, the **ugfile**'s extent is used to compute the look from and look at points if they were not set in the camera statement. The default up direction is the y axis. The default viewing angle is 30 degrees. The default focal length (and film size) are chosen to make sure the whole scene is visible. Use the UG_CAMERA flags to control which viewing options are considered set.

**UGllist ***
**UGalloc_llist(void)**

Allocates the data structure for a single light (a light list of one element).

**void**
**UGadd_llist(UGllist *llist, UGstmt *stmt, int loc, UGllist *ptr)**

Adds the light **llist** to the given UG_LIGHT_STMT statement. **Loc** and **ptr** have the same meaning as in UGadd_stmt. (UG_ARB is not currently implemented, however.)

**void**
**UGfree_llist(UGllist *beg)**

Release the memory used for the light list.

### TRANSFORMATIONS

**BOOL**
**UGadd_tform(UGtform *tform, UGtlist *tlist, int loc, UGtform *ptr)**

Adds the transform **tform** to the transformation list **tlist**. **Loc** and **ptr** have the same meaning as in UGadd_stmt. (UG_ARB is not currently implemented, however.) When adding a transformation there is no need to compute the matrix — simply fill in the transformation name and parameters using the UG_TFORM macros. If you change part of a transformation after it has been added, you must set the UG_TFORM_MAT_OK and UG_TLIST_MAT_OK flags to FALSE, to make sure that the matrix will be recomputed the next time it is asked for. For -M3 and -M4 transformations, you may set the UG_TFORM_MIRROR macro if you want contours to be reversed. This is set automatically for -m? transforms.

**BOOL**
**UGdelete_tform(UGtform *tform, UGtlist *tlist)**

Removes **tform** from **tlist**. Not implemented. (Of course you can always set it to an identity transform and clear the matrix OK flags ...).

## EXTENTS

Typically you will use the _EXTENT macros instead of using the following routines, because bounding box extents are maintained automatically for instance, array, and definitions statements.

**UGextent ∗**
**UGnew_extent(UGextent ∗∗pext)**

Allocates an extent, saves it in ∗**pext**, and return it.

**UGextent ∗**
**UGtform_extent(UGextent ∗out, const UGextent ∗in, MATmatrix matrix)**

Transforms the extent by the given non-projective **matrix**, place the result in **out**, and return it.

**UGextent ∗**
**UGmerge_extent(UGextent ∗in_out, const UGextent ∗in)**

Combines two extents, place the result back into the first one, and return it.

**UGextent ∗**
**UGclear_extent(UGextent ∗∗pext)**

Clears an extent by setting the minimum values to the largest positive floating point value and maximun values to the negative of the minimum values.

**void**
**UGclear_stmt_extent(UGstmt ∗)**

Recursively, clears the extent for the given instance, array, or definition statement and all definitions/instances/arrays that refer to it.

## ROUTINES FOR MANIPULATING TOPOLOGY

Edge lists (UGelist's) are doubly, circularly linked lists, each element of which contains a reference (see UGalloc_ref) to an edge, and a direction. A contour statement has a UGelist as it's only data item. The references in the UGelist are indices into a contour's FROM list. Keep in mind that for a face contour, the edge that connects the last vertex to the first must still be explicit — wire contours are circularly linked also. Similarly, faces and wires have UGclist's which are lists of references to contours. It is always up to you to be sure that edge lists are consistent, *i.e.* that the last vertex of one edge matches the first vertex of the next edge (keeping in mind the ELIST_DIRection).

The clist manipulation routines are a subset of the elist routines if you ignore all references to direction and replace all UGelist's with UGclist's (new and old are now faces or wires).

**UGelist ∗**
**UGalloc_elist(void)**

**UGclist ∗**
**UGalloc_clist(void)**

Allocates a UGelist, circularly links it to itself, and returns a pointer to it. You must use this routine for all allocation of elists, because all of the following routines assume (and maintain) circular linked-ness for all UGelists.

**UGelist ∗**
**UGsplice_elist(UGelist ∗pos, UGelist ∗new, UGelist ∗∗head)**

**UGclist ∗**
**UGsplice_clist(UGclist ∗pos, UGclist ∗new, UGclist ∗∗head)**

Inserts the list **new** after **pos**. **Pos** is normally an element of the elist pointed to by **head**. If pos is NULL then head is set to point to new. **Head** will typically be the address of a UG_CONTOUR_ELIST. The return value is always ∗head. If new is NULL nothing is done.

**UGelist ***
**UGunsplice_elist(UGelist *beg, UGelist *end, UGelist **head)**

**UGclist ***
**UGunsplice_clist(UGclist *beg, UGclist *end, UGclist **head)**

Separates the list pointed to by *head into two parts. One piece will run from **beg** to **end**, and the remaining piece will still be pointed to ***head**. The return value of the function is a pointer to the list begun by **beg**. If *head is somewhere between beg and end inclusively, it is set to point to any element remaining in the initial list, or NULL if the whole list is unspliced from itself. **Beg** and **end** may be equal.

**UGelist ***
**UGkill_elist(UGelist *beg, UGelist *end, UGelist **head)**

**UGclist ***
**UGkill_clist(UGclist *beg, UGclist *end, UGclist **head)**

Same as UGunsplice_elist, but elements that are unspliced are then freed. Return value is *head.

**UGelist ***
**UGmirror_elist(UGelist *el)**

Reverses the order of all edges in **el** in place and returns a pointer to the elist entry that starts with the same vertex as **el** did. Essentially all of the ELIST_NEXT and ELIST_PREV pointers are swapped, and the ELIST_DIR's are toggled. (Try it on paper).

**UGelist ***
**UGduplicate_elist(UGelist *el)**

**UGclist ***
**UGduplicate_clist(UGclist *el)**

Makes a new copy of **el** and returns a pointer to it.

**UGelist ***
**UGconvert_elist(UGelist *el, UGstmt *new, UGstmt *old)**

**UGclist ***
**UGconvert_clist(UGclist *el, UGstmt *new, UGstmt *old)**

You didn't start to think of elist's as pointing to edges did you? Remember, they contain UGidx's that are relative to a contour's FROM reference list. This routine changes each element of **el** so that it points to the same edges in **new** as it used to in **old**, adding new elements to **new**'s reference FROM list, and taking them out of **old**'s. It also removes the references to **old** in the **el**'s edges's TO list. So a typical operation might be to unsplice some edges from one contour, convert the elist, and splice it into another contour.

**UGelist ***
**UGreplace_edge_in_all(UGstmt *edge, int dir, UGelist *elist, UGstmt *ref_contour)**

For every contour which uses **edge**, we replace **edge** with **elist**. **Elist** is defined relative to **ref_contour**. Dir is the relative direction of elist to the verts in edge, so if edge contains the verts A and B, and elist is AX-YB, dir should equal zero.

## ROUTINES FOR CREATING EDGES AND CONTOURS EASILY

**UGstmt ***
**UGmake_edge(UGstmt *v1, UGstmt *v2, int *dir, UGfile *uf, UGstmt *ptr)**

If an edge already exists connecting **v1** and **v2**, it is returned, and ***dir** is set appropriately (0 if the existing edge lists **v1** first, 1 if it lists **v2** first). If not, a new edge UGstmt is created before **ptr** in

**uf**, ***dir** is set to 0, and the new statement pointer is returned.

**UGelist ***
**UGmake_edge_for_contour(UGstmt *v1, UGstmt *v2, UGfile *uf, UGstmt *contour, UGstmt *ptr)**

Does a UGmake_edge, and creates an elist for **contour** that points to the edge. This new elist has its dir all set, and **contour**'s FROM list is updated to point to the new edge. In other words, the elist that is returned is all ready to be spliced into **contour**.

**UGstmt ***
**UGmake_contour(UGstmt **vlist, BOOL face, UGfile *uf, UGstmt *ptr)**

**Vlist** is an array of pointers to vertex (and/or shadow) UGstmts, terminated by a NULL. Creates and returns a contour UGstmt whose elist contains an edge between each adjacent pair of vertices. If face is TRUE, an additional edge is created from the last vertex to the first vertex. The contour is added to uf before ptr.

**BOOL**
**UGmake_contours(UGstmt *stmt, UGfile *uf, UGstmt **vlist, UGstmt *ptr)**

This is not exactly symmetrical with the previous routine, so read carefully. **Vlist** is now a list of verts of the following form: NULL v1 v2 v3 ... NULL v4 v5 ... NULL ... NULL NULL. Each null separated piece is passed to make_contour, and the result is spliced on to the end of stmt's clist. Stmt should be either a face or a wire statement. This is quite special purpose, but sometimes it is convenient. All of the new contours will be put before **ptr** in **uf**. New clist entries are created for each new contour, and they are spliced on to **stmt**'s clist at the end.

## COLOR

**void**
**UGhls_to_shade(float h, float l, float s, UGshade *color)**

Convert a HLS color triple to RGB color.

**void**
**UGshade_to_hls(UGshade *color, float *h, float *l, float *s)**

Convert a RGB color to a HLS triple.

## DEFINITIONS AND MACROS

**Currently defined statement types:**

UG_ARRAY_STMT
UG_CAMERA_STMT
UG_COLOR_STMT
UG_COMMENT_STMT
UG_CONTOUR_STMT
UG_DEF_STMT
UG_EDGE_STMT
UG_ESCAPE_STMT
UG_FACE_STMT
UG_INSTANCE_STMT
UG_LIGHT_STMT
UG_SHADOW_STMT
UG_TEXTURE_STMT
UG_VERT_STMT
UG_WIRE_STMT

**Currently defined statement flags:**

UG_STMT_SHADOWED
UG_VERT_HAS_NORMAL

UG_FACE_HAS_PLANE_EQ
UG_DEF_IS_SOLID
UG_CAMERA_HAS_FROM
UG_CAMERA_HAS_AT
UG_CAMERA_HAS_UP
UG_CAMERA_HAS_FLEN
UG_CAMERA_HAS_CLIP
UG_CAMERA_HAS_FILM
UG_CAMERA_HAS_ANGLES
UG_CAMERA_HAS_PORTHOLE
UG_COLOR_HAS_EMISSION
UG_COLOR_HAS_AMBIENT
UG_COLOR_HAS_DIFFUSE
UG_COLOR_HAS_SPECULAR
UG_COLOR_HAS_TRANS
UG_COLOR_HAS_SHININESS
UG_INST_HAS_EXTENT
UG_ARRAY_HAS_EXTENT

**Macro parameter types:**

uf = UGfile *
us = UGstmt *
utf = UGtform *
utl = UGtlist *
cl = UGclist *
el = UGelist *
ll = UGllist *
sh = UGshade *
idx = UGidx = int
type = int

A UGref is equivalent to a UGstmt **.

**Macros for files and statements:**

| | | |
|---|---|---|
| UGstmt * | UG_FIRST_TYPE(uf, type) | *first statement of this type* |
| UGstmt * | UG_LAST_TYPE(uf, type) | *last statement of this type* |
| int | UG_FILE_LLN(uf) | *Lexical Level Number (scope #) of UGfile* |
| UGextent * | UG_FILE_EXTENT(uf) | *extent of UGfile* |
| | | |
| UGstmt * | UG_NEXT_TYPE(us) | *next statement of same type* |
| UGstmt * | UG_NEXT_TYPE_SAFE(us) | *same with guard against NULL us* |
| UGstmt * | UG_PREV_TYPE(us) | *previous statement of same type* |
| char * | UG_STMT_NAME(us) | *statement's optional name* |
| int | UG_STMT_TYPE(us) | *statement's type* |
| UGfile * | UG_STMT_FILE(us) | *UGfile statement belongs to* |
| int | UG_STMT_LLN(us) | *LLN of UGfile statement belongs to* |
| void * | UG_STMT_APPL(us) | *application data — not touched by library* |
| void * | UG_STMT_EXTRA(us) | *used for instance traversal — available otherwise* |
| UGref [] | UG_STMT_TO(us) | *references TO this statement* |
| UGref [] | UG_STMT_FROM(us) | *references FROM this statement* |
| int | UG_STMT_TO_COUNT(us) | *number of references TO this statement* |
| int | UG_STMT_FROM_COUNT(us) | *number of references FROM this statement* |

**Reference macros:**

| | | |
|---|---|---|
| UGref | UG_REF_TO(us, idx) | |
| UGref | UG_REF_FROM(us, idx) | |

**Flag macros:**

| | | |
|---|---|---|
| BOOL | UG_STMT_FLAG_SET(us, flag) | *test if statement flag is set* |
| void | UG_STMT_SET_FLAG(us, flag) | *set statement flag* |
| void | UG_STMT_CLEAR_FLAG(us, flag) | *clear statement flag* |

**Loop macros:**

| | |
|---|---|
| UG_FOR_ALL_STMTS(us, uf, type) | *visit all statements in uf* |
| UG_FOR_ALL_STMTS_SAFE(us, uf, type, tmp_us) | |
| UG_FOR_ALL_STMTS_REALLY(us, uf, type, tmp_us) | *even shadow statements* |
| UG_FOR_ALL_TYPE(us, uf, type) | |
| UG_FOR_ALL_TYPE_SAFE(us, uf, type, tmp_us) | |
| UG_FOR_ALL_TFORMS(utf, utl) | |
| UG_FOR_ALL_TFORMS_SAFE(utf, utl, tmp_utf) | |

Use the SAFE versions of the macros whenever you might be deleting the object pointed to by the loop variable. The tmp_ variables are used by the loop, but contain no information for the user.

**Macros specific to given statement types:**

| | | |
|---|---|---|
| MATpoint | UG_VERT_POINT(us) | |
| MATpoint | UG_VERT_POINT_SAFE(us) | *follows shadow statements* |
| MATvec | UG_VERT_NORMAL(us) | |
| MATvec | UG_VERT_NORMAL_SAFE(us) | *follows shadow statements* |
| UGidx | UG_VERT_COLOR(us) | |
| UGidx | UG_VERT_COLOR_SAFE(us) | *follows shadow statements* |
| UGidx [2] | UG_EDGE_VERTS(us) | |
| UGelist ∗ | UG_CONTOUR_ELIST(us) | |
| UGclist ∗ | UG_FACE_CLIST(us) | |
| MATvec | UG_FACE_PLANE_EQ(us) | |
| UGidx | UG_FACE_COLOR(us) | |
| UGidx | UG_FACE_LIGHTS(us) | |
| float | UG_FACE_LIGHTNESS(us) | |
| UGclist ∗ | UG_WIRE_CLIST(us) | |
| UGidx | UG_WIRE_COLOR(us) | |
| float | UG_WIRE_LIGHTNESS(us) | |
| UGfile ∗ | UG_DEF_BLOCK(us) | |
| UGidx | UG_INSTANCE_DEF(us) | |
| UGidx | UG_INSTANCE_COLOR(us) | |
| UGidx | UG_INSTANCE_LIGHTS(us) | |
| UGtlist ∗ | UG_INSTANCE_TLIST(us) | |
| UGextent ∗ | UG_INSTANCE_EXTENT(us) | |
| UGidx | UG_ARRAY_DEF(us) | |
| UGidx | UG_ARRAY_COLOR(us) | |
| UGidx | UG_ARRAY_LIGHTS(us) | |
| int | UG_ARRAY_SIZE(us) | |
| UGtform ∗ | UG_ARRAY_INIT_TLIST(us) | |
| UGtform ∗ | UG_ARRAY_INC_TLIST(us) | |

| | | |
|---|---|---|
| UGextent * | UG_ARRAY_EXTENT(us) | |
| BOOL | UG_CAMERA_TYPE(us) | *one of UG_CAMERA_{PERS, ORTHO}* |
| MATmatrix | UG_CAMERA_VIEW_MAT(us) | |
| MATmatrix | UG_CAMERA_INV_VIEW_MAT(us) | |
| MATmatrix | UG_CAMERA_PERS_MAT(us) | |
| MATmatrix | UG_CAMERA_INV_PERS_MAT(us) | |
| MATpoint | UG_CAMERA_FROM(us) | |
| MATpoint | UG_CAMERA_AT(us) | |
| MATvec | UG_CAMERA_UP(us) | |
| float | UG_CAMERA_FOCAL_LENGTH(us) | |
| float [2] | UG_CAMERA_FILM_SIZE(us) | |
| float [2] | UG_CAMERA_VIEW_ANGLES(us) | |
| float [2] | UG_CAMERA_CLIP_PLANES(us) | *hither and yon* |
| UGextent | *UG_CAMERA_PORTHOLE(us) | |
| UGllist * | UG_LIGHT_LLIST(us) | *first light in light list* |
| UGllist * | UG_LIGHT_END(us) | *end of light list* |
| int | UG_LLIST_TYPE(ll) | *one of UG_LIGHT_{DIRECT, AMBIENT, POINT}* |
| MATvec | UG_LLIST_DIR(ll) | *actually holds a point if type is _POINT* |
| float | UG_LLIST_INTENS(ll) | *intensity of light* |
| UGidx | UG_LLIST_COLOR(ll) | *color of light* |
| UGshade * | UG_COLOR_EMISSION(us) | |
| UGshade * | UG_COLOR_AMBIENT(us) | |
| UGshade * | UG_COLOR_DIFFUSE(us) | |
| UGshade * | UG_COLOR_SPECULAR(us) | |
| float | UG_COLOR_SHININESS(us) | |
| float | UG_COLOR_TRANS(us) | |
| UGidx | UG_COLOR_TEXTURE(us) | |
| float | UG_SHADE_R(sh) | *red component of shade* |
| float | UG_SHADE_G(sh) | *green component of shade* |
| float | UG_SHADE_B(sh) | *blue component of shade* |
| int | UG_TEXTURE_IMAGE_TYPE(us) | |
| char * | UG_TEXTURE_IMAGE_NAME(us) | |
| int | UG_TEXTURE_IMAGE_WIDTH(us) | |
| int | UG_TEXTURE_IMAGE_HEIGHT(us) | |
| int | UG_TEXTURE_IMAGE_NCOMPONENTS(us) | |
| int | UG_TEXTURE_WRAP(us) | |
| int | UG_TEXTURE_MINFILTER(us) | |
| int | UG_TEXTURE_MAGFILTER(us) | |
| float | UG_TEXTURE_USCALE(us) | |
| float | UG_TEXTURE_VSCALE(us) | |
| void * | UG_TEXTURE_IMAGE(us) | |
| void * | UG_ESCAPE_TAG(us) | *can be used to classify escape statments* |
| char * | UG_ESCAPE_TEXT(us) | |
| char * | UG_COMMENT_TEXT(us) | |
| int | UG_SHADOW_TYPE(us) | *type of statement being shadowed* |
| UGidx | UG_SHADOW_LINK(us) | |

**Macros for contour and edge lists:**

| | | |
|---|---|---|
| UGidx | UG_CLIST_CONTOUR(cl) | |
| UGclist ∗ | UG_CLIST_NEXT(cl) | *circularly, doubly linked* |
| UGclist ∗ | UG_CLIST_PREV(cl) | |
| UGidx | UG_ELIST_EDGE(el) | |
| int | UG_ELIST_DIR(el) | *index (0 or 1) into EDGE_VERTS of first vertex* |
| UGelist ∗ | UG_ELIST_NEXT(el) | *Circularly, doubly linked* |
| UGelist ∗ | UG_ELIST_PREV(el) | |

**Macros for handling transforms:**

| | | |
|---|---|---|
| char [3] | UG_TFORM_TYPE(utf) | |
| MATreal [16] | UG_TFORM_PARAMS(utf) | |
| int | UG_TFORM_NUM_PARAMS(utf) | |
| MATmatrix | UG_TFORM_MAT(utf) | *maintained for you* |
| BOOL | UG_TFORM_MAT_OK(utf) | *clear if you change a tform after UGadd_tform'ing it* |
| UGtform | ∗UG_TFORM_NEXT(utf) | |
| BOOL | UG_TFORM_MIRROR(utf) | *TRUE if contours should reverse* |
| MATmatrix | UG_TLIST_MAT(utl) | *maintained for you* |
| BOOL | UG_TLIST_MAT_OK(utl) | *clear this if you change any tform* |
| UGtform ∗ | UG_TLIST_TFORMS(utl) | |
| BOOL | UG_TLIST_MIRROR(utl) | |

**ENVIRONMENT**

UGMODELPATH — a colon separated list directories to search for include files

**SEE ALSO**

mat(3), compat(3)

**AUTHOR**

Michael Natkin, February through April 1987
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## UG

ug — UNIGRAFIX file format

## DESCRIPTION

The following is a pseudo BNF description of the UNIGRAFIX file format. Literals are in boldface, except for punctuation which is enclosed in single quotes ‘ ’. Variables are are in italics. Optional parts are enclosed in square brackets, [ ]. Zero or more repetitions are enclosed in curly braces, { }. Alternatives are separated by vertical bars, **|**.

By default, all variables are real numbers, with the following exceptions: *size* and *line_no* are integers; *text* and *filename* are arbitrary strings; *id* is a string consisting of upper and lowercase chars, digits, colon (:), underscore (_) and sharp (#) — but not beginning with a digit; *materialID*, *vertexID*, *definitionID*, *lightsID*, and *textureID* are *id*’s of the appropriate statement type.

Left curly brace, {, and right curly brace, }, are comment delimiters and may be nested. White space is always ignored except to separate fields.

file : statements
statements
  : statement { statement }
statement
  : vertex **|** wire **|** face **|** definition **|** instance **|** array
  **|** color **|** material **|** texture **|** lights **|** camera
  **|** include **|** execute **|** cpp **|** escape
vertex : **v** *id x y z* [*w*] [*materialID*] ’;’
wire : **w** [*id*] contours [*materialID*] ’;’
face : **f** [*id*] contours [*materialID*] ’;’
definition
  : **def** *id* [**solid**] ’;’ statements **end** ’;’
instance : **i** [*id*] ’(’ *definitionID* [*materialID*] [*lightsID*] [tforms] ’)’ ’;’
array : **a** [*id*] ’(’ *definitionID* [*materialID*] [*lightsID*] [tforms] ’)’ *size* [tforms] ’;’
color : **c**[**olor**] [*id*] *lightness* [*hue* [*saturation* [*translucency*]]] ’;’
  **| c**[**olor**]**_rgb** [*id*] *red green blue* [*translucency*] [*textureID*] ’;’
material : **defmat** *id* ’;’ material_statements **end** ’;’
material_statements
  : material_statement { material_statement }
material_statement
  : **c**[**olor**] *lightness* [*hue* [*saturation*]] ’;’
  **| c**[**olor**]**_rgb** *red green blue* ’;’
  **| emission** *lightness* [*hue* [*saturation*]] ’;’
  **| emission_rgb** *red green blue* ’;’
  **| ambient** *lightness* [*hue* [*saturation*]] ’;’
  **| ambient_rgb** *red green blue* ’;’
  **| diffuse** *lightness* [*hue* [*saturation*]] ’;’
  **| diffuse_rgb** *red green blue* ’;’
  **| specular** *lightness* [*hue* [*saturation*]] ’;’
  **| specular_rgb** *red green blue* ’;’
  **| shininess** *exponent* ’;’
  **| opacity** *translucency* ’;’
  **| texture** *textureID* ’;’
texture : **deftex** *id* ’;’ texture_statements **end** ’;’
texture_statements
  : texture_statement { texture_statement }
texture_statement
  : **t_file** *filename* ’;’
  **| t_type** *type* ’;’

| | |
|---|---|
| | **| t_size** *width height num_components* ’;’ |
| | **| t_wrap** *style* ’;’ |
| | **| t_filter** *min_filter mag_filter* ’;’ |
| | **| t_scale** *u_scale v_scale* ’;’ |
| lights | : **deflights** *id* ’;’ light_statements **end** ’;’ |
| light_statements | |
| | : light_statement { light_statement } |
| light_statement | |
| | : **l** *intensity* [*x y z* [w]] [*materialID*] ’;’ |
| camera | : **cam** [*id*] viewing_options ’;’ |
| viewing_options | |
| | : viewing_option { viewing_option } |
| viewing_option | |
| | : **–og** |
| | \| **–ps** |
| | \| **–vc** *x y z* |
| | \| **–ep** *x y z* |
| | \| **–ud** *dx dy dz* |
| | \| **–cl** *hither yon* |
| | \| **–ph** *minx miny maxx maxy* |
| | \| **–va** *sx sy* |
| | \| **–fs** *sx sy* |
| | \| **–fl** *len* |
| include | : **include** *filename* ’;’ |
| execute | : **execute** *filename* ’;’ |
| cpp | : ’#’ *line_no* ’"’*filename*’"’ |
| escape | : **(** [*text*] [escape] [*text*] ’)’ |
| contours | : contour { contour } |
| contour | : ’(’ *vertexID* { *vertexID* ’)’ |
| tforms | : tform { tform } |
| tform | : **–sx** *amt* **\|** **–sy** *amt* **\|** **–sz** *amt* |
| | \| **–sa** *amt* \| **–sv** *x y z amt* |
| | \| **–tx** *amt* \| **–ty** *amt* \| **–tz** *amt* |
| | \| **–ta** *amt* \| **–tv** *x y z amt* |
| | \| **–rx** *amt* \| **–ry** *amt* \| **–rz** *amt* |
| | \| **–rv** *x y z amt* |
| | \| **–mx** \| **–my** \| **–mz** \| **–ma** |
| | \| **–mv** *x y z* |
| | \| **–M3** *a11 a12 a13 a21 a22 a23 a31 a32 a33* |
| | \| **–M4** *a11 a12 a13 a14 a21 a22 a23 a24 a31 a32 a33 a34 a41 a42 a43 a44* |

UNIGRAFIX uses a right-handed coordinate system with the vertices in the outermost contour of a face given in counter-clockwise order.

## VIEWING OPTIONS

Each viewing option may only be given once.

projective transformation type

**–og** set orthographic mode (the default). **–ps** sets perspective mode.

World to Eye Coordinates

**–vc** sets the view center (the look at point). **–ep** sets the eye point (the look from point). **–ud** sets the up direction (a vector, not a point).

Eye Coordinates to Canonical View Volume

**–va** sets the viewing angles. **–fs** sets the film size. **–fl** sets the focal length. Only two out of **–va**, **–fs**, and **–va** should be set. **–cl** sets the hither and yon clipping planes (in view volume coordinates). **–ph** sets the porthole in the viewport to render (expressed in normalized device coordinates).

**TRANSFORMS**

All transformations follow a regular two letter code except for **-M3** and **-M4** which concatenate an arbitrary 3 by 3 or 4 by 4 matrix respectively.

The possibilities for the first letter are: *s* is for scaling, *t* is for translation, *r* is for rotation, and *m* if for mirroring (negative scaling with face vertex reversal).

The possibilities for the second letter are: *x* is for about/along the x-axis, *y* is for about/along the y-axis, *z* is for about/along the z-axis, *a* is for about/along all of the axes, and *v* is for about/along a particular vector.

**SEE ALSO**

ug(3)