MP2GL: Prototyping 3D Objects with MetaPost and OpenGL

Denis Roegel, University of Nancy, France
roegel@loria.fr

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Summary

- Limitations of MetaPost
- Motivations of MP2GL
- OpenGL
- MP2GL interface
- 3D equations
- Text
- Animations
- Lights, color, ...
- Limitations of MP2GL
- Related work

Limitations of MetaPost

- MetaPost is not adapted to 3D
- a hidden faces algorithm needs to be implemented
- lights
- colors
- numerical limitations
- static view

Motivations of MP2GL

Two remedies can be envisioned, at a non-macro level:

- extending the core MetaPost with 3D support: a lot of work in perspective... (no case known)

- using an external processor:
  - not 3D-aware: a lot of work... (3DLDF)
  - 3D-aware: easy (MP2GL)

Question: do we need a 3D-MetaPost?

In order to answer that question, let's see good reasons to use 2D-MetaPost:

- TEX partner;
- high-quality technical drawings;
- vector graphics;
- declarative approach;
- nice types;
- fun!

Among these reasons, the intrinsic MetaPost ones are:

- TEX partner;
- declarative approach;
- nice types;

A 3D-MetaPost would include the 2D-MetaPost features, plus:

- 3D vector graphics;
- animations.

Our proposal: MP2GL

MP2GL = MetaPost to OpenGL

- OpenGL: standard API for graphics in the industry;
- rendering of 3D scenes, with lights, shading, hidden faces removal (z-buffer), etc.
- scenes can be saved in bitmap, and in PS, using the GL2PS library.

A motivation for 2D $\Rightarrow$ 3D

Most 3D objects that one wants to build are:

- either geometrically very simple (cube, ...)
- or obtained simply from 2D objects (prism, ...)
- or composed of simpler 3D objects.

These three ways of building an object are supported in MP2GL.

Main features of MP2GL

- MetaPost input language;
- structures for points and homogeneous coordinates;
- interface to OpenGL objects (polyhedra, ...)
- ability to build low-level objects;
- MetaPost paths can be used to build prisms;
- equations can be used in 3D;
- production of C-code with a minimal animation interface;

- a scene can be saved in bitmap and PS;
- TEX labels can be added and later adjusted;
- the C output is editable and can be used without MetaPost;
- objects can be created on the OpenGL side;

MP2GL should be seen as a *gateway* from MetaPost to OpenGL, both for the objects and for the user.

OpenGL

An OpenGL scene is created by translations and rotations, and polygons defined by vertices.

A tetrahedron at $(-4.1, 5, 12.3)$ is obtained with:

```
glTranslatef(-4.1,5,12.3);
glutSolidTetrahedron();
```

A square can be built with:

```
glBegin(GL_POLYGON);
  glNormal3f(0,0,1);
  glVertex3f(0,0,0);
  glVertex3f(1,0,0);
  glVertex3f(1,1,0);
  glVertex3f(0,1,0);
glEnd();
```

MP2GL interface: types

The `color` type is used for points:

```
def Point = color enddef;
def Xpart = redpart enddef;
def Ypart = greenpart enddef;
def Zpart = bluepart enddef;
```

MP2GL interface: transformations

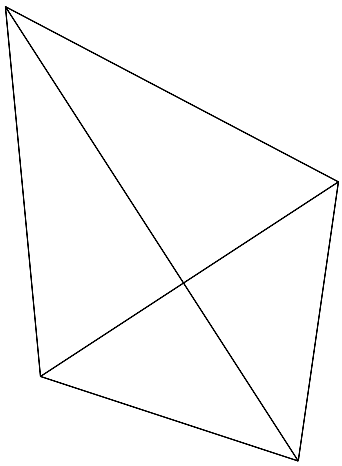
- Translations, rotations, etc.
- MetaPost mimicks OpenGL:
  - `Translate` → `glTranslatef`
  - ...
  - `PushPosition`, `PopPosition`

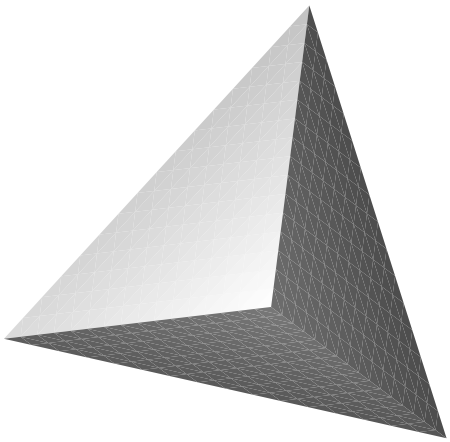
These transformations are:

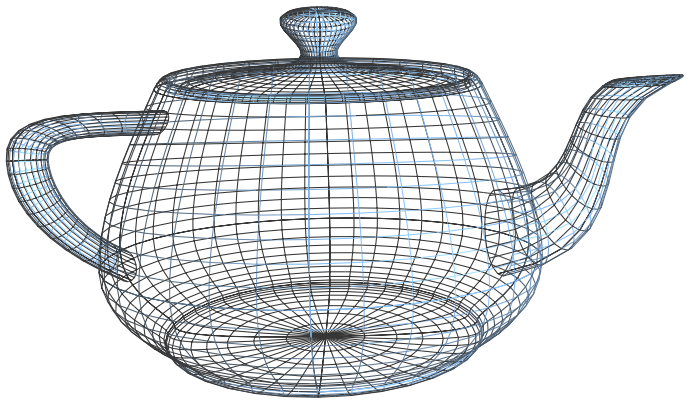
- output in C;
- processed internally in order to maintain a "current transformation" which can be used if necessary;

MP2GL interface: basic objects

Polyhedra, sphere, cone, torus, teapot, disk, partial disk, cylinder.







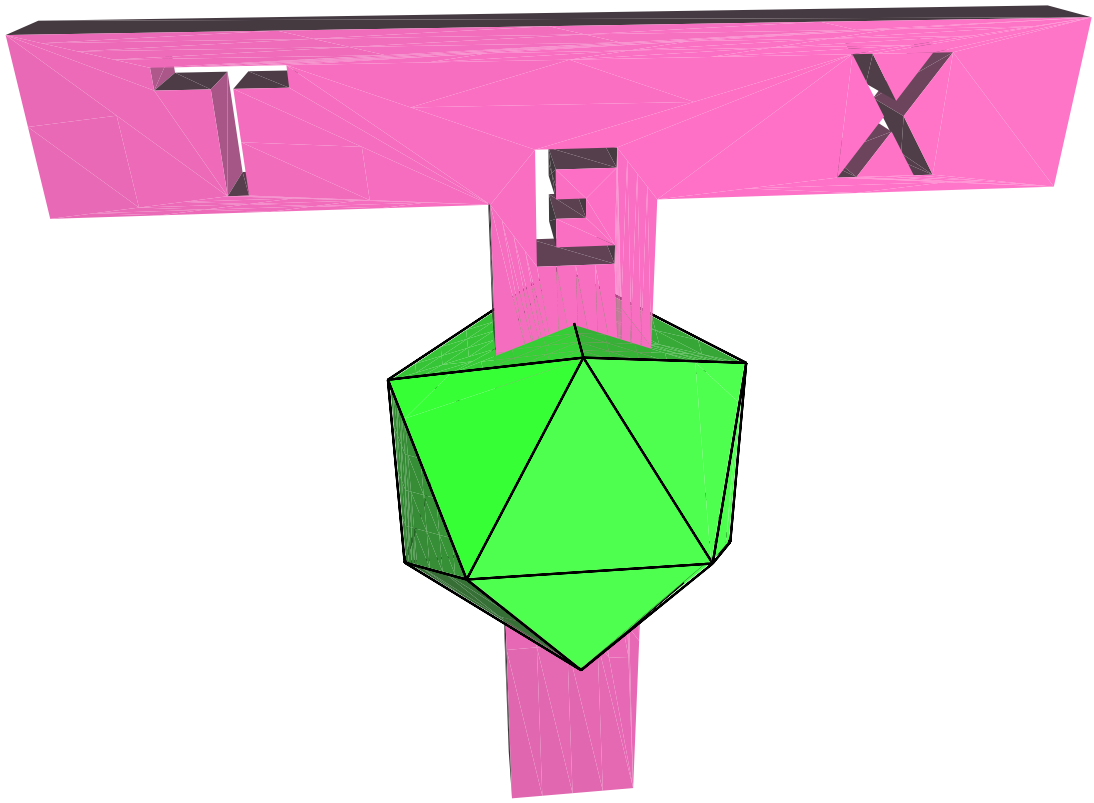
MP2GL interface: path-based objects

```
path p;
p=......--cycle;
storepath(p,"Path_P");

new_prism("Prism1","Path_P",3cm);

begin_scene;
  use_object("Prism1");
end_scene;
```

A more complex example, made of four paths:



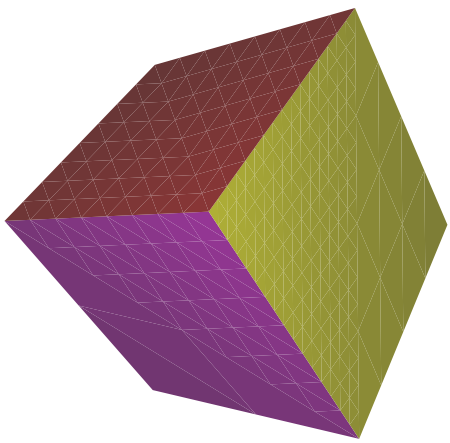
MP2GL interface: low-level

A cube can be constructed face by face:

```
def build_cube_face=
  begin_convex_polygon;
    normal(0,0,-1);
    vertex(0,0,0);
    vertex(0,1,0);
    vertex(1,1,0);
    vertex(1,0,0);
  end_convex_polygon;
enddef;
```

MP2GL interface: low-level (cont'ed)

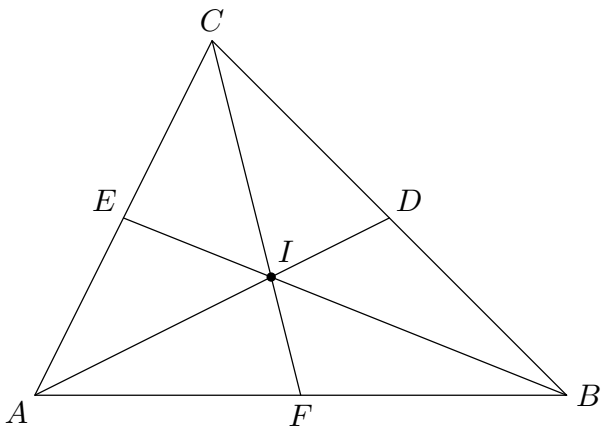
```
beginobject("Cube");
  set_diffuse_color(1.0,0.0,0.0);
  build_cube_face; % bottom face
  PushPosition;
    Translate(1,0,0);RotateY(-90);
    set_diffuse_color(0.0,1.0,0.0);
    build_cube_face;
    ...
endobject
```



3D equations

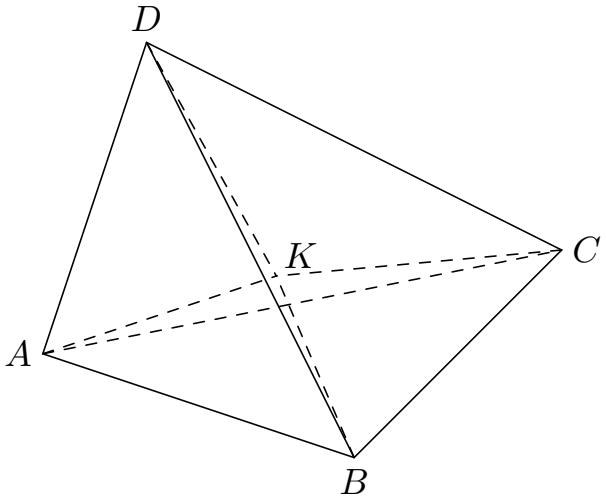
Equations are a powerful way to define positions through linear constraints in MetaPost.

```
D=.5[B,C];E=.5[C,A];F=.5[A,B];
I=whatever[B,E]=whatever[A,D];
```



The same mechanism can be used on points in space, within MetaPost.

3D equations: splitting a tetrahedron ... (1)



Point K can be obtained by similar means:

```
E=.5[B,C];  F=.5[C,D];  G=.5[B,D];
H=.5[A,D];  I=.5[A,B];  J=.5[A,C];

K=whatever[G,J]=whatever[H,E];
```

3D equations: ... into four tetrahedra (2)

```
new_tetrahedron("t1",A,B,C,K);
new_tetrahedron("t2",C,B,D,K);
new_tetrahedron("t3",A,C,D,K);
new_tetrahedron("t4",B,A,D,K);
```

We are going to move these four tetrahedra, and the four new vertices will be used to insert a sphere.

MetaPost can be used to compute the center of that sphere, as well as its radius, by ordinary equations (and a little bit of `whatever` abuse...):

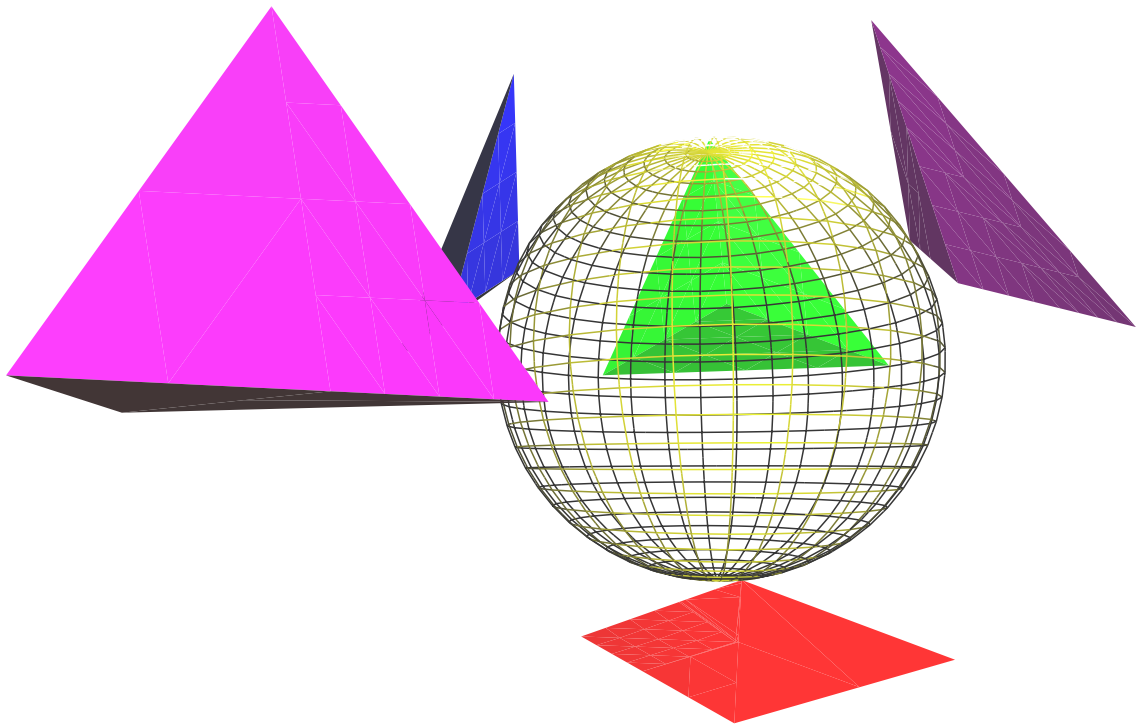
```
...
V9=V1+whatever*V2+whatever*V3
  =V4+whatever*V2+whatever*V5
  =V6+whatever*V7+whatever*V8;
```

(six different values of `whatever`!)

3D equations: ... into four tetrahedra (3)

The resulting construction is the following:

```
begin_scene;
  PushPosition;
    TranslateV(K-D);
    use_object("t1");
  PopPosition;
  ...
  TranslateV(V9);
  wire_sphere(norm(W1-V9),30,30);
end_scene;
```



Text

- TEX labels can be added at specific projected locations; the TEX output can be edited;

- labels are not in space;

- text in space could be obtained with the appropriate objects, created from paths;

- other features could be added, for instance fake labels, or a second processing through MetaPost.

Animations

- the output of MP2GL is an interactive animation;
- the user has a minimal interface for moving around the scene; all positions are reachable;
- the scene can be saved as JPEG or PS; other formats (such as PPM, or PDF) are easy to add;
- the animation can be edited, for instance for changing the lights, colors, the camera, etc.
- the animation could be extended in order to produce a series of bitmaps, which could then be made into an MPEG;

Lights, colors, ...

- lights are hardwired, but future versions of MP2GL may make them changeable; they can currently be changed in OpenGL;

- colors follow the OpenGL model (emission, ambient, diffuse, specular);

Limitations of MP2GL

Many features will be added (for instance NURBS), but there are also hard(er) limitations:

- of GL2PS:
  - no textures in PS output;
  - no transparency in PS output;
- of OpenGL:
  - no shadows
  - no CSG construction

Related work

- `3d`,
- `m3dplain`,
- `featpost`,
- `pstricks`
- `3DLDF`: most promising.

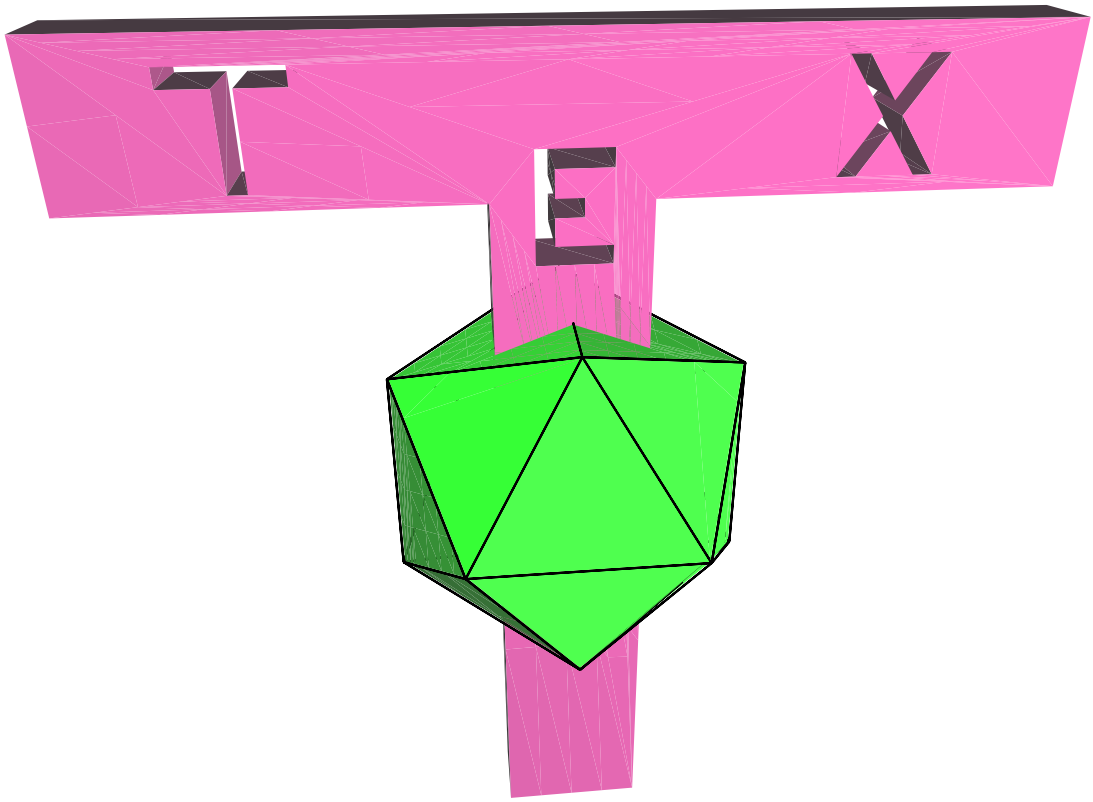
Conclusion

The aim of this study was:

- to examine the feasability of a bridge between MetaPost and OpenGL;
- to easily obtain 3D vector graphics for inclusion in a document;
- to obtain 3D objects for further processing, for instance in an independent OpenGL application.

These goals have all be met, although many features still have to be added.

Thanks!



http://www.loria.fr/~roegel

roegel@loria.fr