Calculations

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1 Computations on dP6

1.1 Finding equations of deformations

Consider the del Pezzo surface dP_6 of degree 6 embedded in $\mathbb{P}^6$. Its ideal is defined as follows:

```
restart
S = QQ[x_1..x_6,y_0]
I = ideal(x_1*x_3-x_2*y_0,
        x_2*x_4-x_3*y_0,
  x_3*x_5-x_4*y_0,
  x_4*x_6-x_5*y_0,
  x_5*x_1-x_6*y_0,
  x_6*x_2-x_1*y_0,
  x_1*x_4-y_0^2,
  x_2*x_5-y_0^2,
  x_3*x_6-y_0^2)
```

We compute the two deformations of its affine cone using the package `VersalDeformations`.

```
(F,R,G,C) = versalDeformation(gens I);
decompose ideal transpose mingens ideal G
```

The output are four lists of matrices entries in $\mathbb{Q}[\mathbf{x}] \otimes \mathbb{Q}[t_1, t_2, t_3]$. The list F consists of the equations of the family, and the list R of the relations. The list G gives equations for the base space. We have that F_0 is the matrix of generators of I, and that $F_i R_i \equiv 0 \pmod{t^{i+1}}$.

The decomposition of `ideal G` is the following:

```
i9 : decompose ideal transpose mingens ideal G

o9 = {ideal(t  - t ), ideal (t  - t , t )}
             1    3           2    3   1
```

Thus the base space splits into two components meeting transversely at the origin, of dimension 2 and 1, respectively. By doing a change of variables we can get rid of the linear terms:

```
T = QQ[x_1..x_6,y_0,t_1,t_2,t_3,s_1,s_2,s_3];
gsub = sub(sub(ideal mingens ideal G,T), {t_2 => s_2+s_3-s_1,
    t_1 => s_3, t_3 => s_3-s_1})
fsub = transpose  sub(sub(sum F,T), {t_2 => s_2+s_3-s_1, t_1 =>
    s_3, t_3 => s_3-s_1})
```

Now the equations are easier:

```
i13 : decompose gsub

o13 = {ideal(s ), ideal (s , s )}
              1          3   2
```

We can get equations for each of these families by setting $s_1 = 0$ and $s_3 = s_2 = 0$, respectively:

```
i25 : fsub1 = sub(fsub, s_1 => 0)

o25 = {-2} | x_1x_3-x_2y_0                              |
      {-2} | x_2x_4-x_3y_0+x_3s_2+x_3s_3                |
      {-2} | x_3x_5-x_4y_0+x_4s_3                       |
      {-2} | x_4x_6-x_5y_0                              |
      {-2} | x_1x_5-x_6y_0+x_6s_2+x_6s_3                |
      {-2} | x_2x_6-x_1y_0+x_1s_3                       |
      {-2} | x_1x_4-y_0^2+y_0s_2+y_0s_3                 |
      {-2} | x_2x_5-y_0^2+y_0s_2+2y_0s_3-s_2s_3-s_3^2   |
      {-2} | x_3x_6-y_0^2+y_0s_3                        |

              9       1
o25 : Matrix T  <--- T
```

And:

```
i26 : fsub2 = sub(fsub, {s_3 => 0, s_2 => 0})

o26 = {-2} | x_1x_3-x_2y_0          |
      {-2} | x_2x_4-x_3y_0-x_3s_1   |
      {-2} | x_3x_5-x_4y_0          |
      {-2} | x_4x_6-x_5y_0-x_5s_1   |
      {-2} | x_1x_5-x_6y_0          |
      {-2} | x_2x_6-x_1y_0-x_1s_1   |
      {-2} | x_1x_4-y_0^2-y_0s_1    |
      {-2} | x_2x_5-y_0^2-y_0s_1    |
      {-2} | x_3x_6-y_0^2-y_0s_1    |

              9       1
o26 : Matrix T  <--- T
```

1.2 Intersecting with two special hyperplanes

Consider dP_6 defined as above. Then consider the two hyperplanes

$$h_1 = x_1 + x_2 + x_3 + x_4 + x_5 + x_6$$

and

$$h_2 = x_1 - x_2 + x_3 - x_4 + x_5 - x_6.$$

We can compute the intersection with dP_6 in `Macaulay2` as follows:

```
h1 = x_1+x_2+x_3+x_4+x_5+x_6
h2 = x_1-x_2+x_3-x_4+x_5-x_6

SS = S[r]/(r^2+3)
apply(decompose(sub(I + h1 + h2,SS)), j -> ideal mingens sub(j,
    y_0 => 1))
```

The reason we create a new ring is that we need $\sqrt{-3}$ in order for the ideals to decompose. The results is the following list of ideals:

1. $(x_5 - 1, x_4 + x_6 + 1, x_3 + x_6 + 1, x_2 - 1, x_1 - x_6, r - 2x_6 - 1)$.
2. $(x_5 - 1, x_4 + x_6 + 1, x_3 + x_6 + 1, x_2 - 1, x_1 - x_6, r + 2x_6 + 1)$.
3. $(x_6 - 1, x_4 - x_5, x_3 - 1, x_2 + x_5 + 1, x_1 + x_5 + 1, r - 2x_5 - 1)$.
4. $(x_6 - 1, x_4 - x_5, x_3 - 1, x_2 + x_5 + 1, x_1 + x_5 + 1, r + 2x_5 + 1)$.
5. $(x_5 - x_6, x_4 - 1, x_3 + x_6 + 1, x_2 + x_6 + 1, x_1 - 1, r - 2x_6 - 1)$.
6. $(x_5 - x_6, x_4 - 1, x_3 + x_6 + 1, x_2 + x_6 + 1, x_1 - 1, r + 2x_6 + 1)$.

From this we can read off the coordinates in $\mathbb{P}^6$:

Note that the hexagonal group D_6 act transitively on the set of singular points.

1.3 Intersecting with another set of hyperplanes

Note that the group $\mathbb{Z}_2 \times \mathbb{Z}_2$ act on dP_6 by reflecting the triangulation in Figure 1a (in fact $\mathbb{Z}_2\mathbf{x}\mathbb{Z}_2$ is a subgroup of D_6). $\mathbb{Z}_2 \times \mathbb{Z}_2$ is the full symmetry group of the triangulation in the figure.

Table 1: Table of singular points.

x_1	x_2	x_3	x_4	x_5	x_6	y_0
$\frac{-1+\sqrt{3}}{2}$	1	$\frac{-1-\sqrt{-3}}{2}$	$\frac{-1-\sqrt{-3}}{2}$	1	$\frac{-1+\sqrt{-3}}{2}$	1
$\frac{-1+\sqrt{-3}}{2}$	1	$\frac{-1+\sqrt{-3}}{2}$	$\frac{-1+\sqrt{-3}}{2}$	1	$\frac{-1-\sqrt{-3}}{2}$	1
$\frac{-1-\sqrt{-3}}{2}$	$\frac{-1-\sqrt{-3}}{2}$	1	$\frac{-1+\sqrt{-3}}{2}$	$\frac{-1+\sqrt{-3}}{2}$	1	1
$\frac{-1+\sqrt{-3}}{2}$	$\frac{-1+\sqrt{-3}}{2}$	1	$\frac{-1-\sqrt{-3}}{2}$	$\frac{-1-\sqrt{-3}}{2}$	1	1
1	$\frac{-1-\sqrt{-3}}{2}$	$\frac{-1-\sqrt{-3}}{2}$	1	$\frac{-1+\sqrt{-3}}{2}$	$\frac{-1+\sqrt{-3}}{2}$	1
1	$\frac{-1+\sqrt{-3}}{2}$	$\frac{-1+\sqrt{-3}}{2}$	1	$\frac{-1-\sqrt{-3}}{2}$	$\frac{-1-\sqrt{-3}}{2}$	1

2 Toric mirrors

2.1 First example

There are two examples of torics we have studied. The first one is this.

Let I and I' be the ideals of dP_6 with a disjoint set of variables. Let $J = I + I'$.

Remark. *This is a deformation of the Stanley-Reisner scheme corresponding to the join of two hexagons and two points.*

Then $Y_0 = \mathrm{Proj}(S/J)$ is a toric variety whose associated polytope P has vertices the column of the following matrix:

$$\begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & -2 & 2 & 0 & -2 & 0 & 2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2 & -2 & 2 & 2 \\ -2 & 2 & 0 & -2 & 0 & 2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -2 & -2 & 2 & 2 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix} \tag{1}$$

The polytope P is reflexive with 87 lattice points. We can use the Batyrev-Borisov construction to find a toric mirror candidate to Y_0.

The construction actually give two such families. Here's how: start with a reflexive polytope $P \subset M_{\mathbb{R}}$. A *nef partition* induces a decomposition

V_1, V_2 of the vertex set of $P^\vee \subset N_\mathbb{R}$, such that $P^\vee = \mathrm{conv}(V_1, V_2)$. Let $Q_i = \mathrm{conv}(V_i)$. Then one forms $Q := Q_1 + Q_2 \subset N_\mathbb{R}$. Similarly, we have a dual nef partition, so that we can write $P = P_1 + P_2$.

A nef partition correspond to a complete intersection in X_P, and the dual nef partition correspond to a complete intersection in X_Q.

We can find (using SAGE for example) the polytopes P_1 and P_2. They are given as follows:

$$P_1 = \mathrm{conv}\begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & -1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & -1 \\ -1 & -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix} \tag{2}$$

and

$$P_2 = \mathrm{conv}\begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & -1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 1 & 1 & 0 & -1 \\ -1 & -1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \tag{3}$$

There is a formula for the Q_i given the P_i:

$$Q_i = \{u \in N_\mathbb{R} \mid \langle u, m\rangle \geq -1 \text{ for all } \ m \in P_i, \langle u, m\rangle \geq 0 \,\forall\, m \in P_j, j \neq i\}$$

Then we find that Q_1 is given by

$$Q_1 = \mathrm{conv}\begin{pmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & -1 & 0 & 1 & -1 & 0 \\ -1 & -1 & -1 & 0 & -1 & -1 & -1 \end{pmatrix} \tag{4}$$

and

$$Q_2 = \operatorname{conv}\begin{pmatrix} -1 & -1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & -1 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 1 & 1 & 1 \end{pmatrix} \tag{5}$$

The polytope Q has 48 vertices:

$$\left(\begin{smallmatrix} -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 1 & 0 & 1 & 1 & -1 & -1 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 0 & 0 & 1 & 1 & -1 & -1 & 0 & 0 & 0 & 1 \\ 0 & 1 & -1 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 0 & 1 & -1 & 0 & 0 & 1 & -1 & 0 & 1 & -1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1 & -1 & -1 & 0 & -1 & -1 & -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{smallmatrix}\right)$$

The polar polytope $Q^\vee$ is given by

$$\begin{pmatrix} -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ -1 & -1 & 0 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & -1 & -1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & -1 & 0 & 0 & -1 & -1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & -1 & 0 & -1 & 0 & -1 & 0 & -1 & 0 & -1 & 0 & -1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 \end{pmatrix}$$

One can use the program `nef_x` (written by Skarke et al) to compute the Hodge numbers corresponding to the nef partitions $P_1 + P_2$ and $Q_1 + Q_2$. It turns out that they are $(19, 19)$.

2.2 Second example

Again consider two copies of the homogeneous ideal of dP_6. This time, however, embed them by mapping the origins in their polytopes to the same monomial. This is the same as letting $y_0 = y_1$ in the previous example, where y_i correspond to the origins of the polytopes. The corresponding polytope is just the product of two hexagons.

Remark. *This is a deformation of the Stanley-Reisner scheme corresponding to the join of two hexagons and a point.*

We get a 4-dimensional toric variety Y_0'. Here, running `nef_x` gives Hodge numbers $(44, 8)$, giving an Euler characteristic of 72.

Remark. *This sounds promising, because earlier I've found a smoothing of this variety with Euler characteristic -72.*

(a) The hexagon in another triangulation.

(b) The hexagon in the pulling triangulation.

Figure 1: Two triangulations of the hexagon.

3 Deformation calculations

3.1 Non-standard triangulation

In Figure 1 are depicted two different triangulations of the hexagon. They correspond to different Gröbner bases of the ideal of dP_6. Choosing the left triangulation turns out to give smaller-dimensional T^2.

Below are some deformation computations done on the Stanley-Reisner scheme corresponding to the join of two hexagons in this triangulation.

```
restart
R1 = QQ[x_1..x_6,y_0]
R2 = QQ[z_1..z_6,y_1]

loadPackage "SimplicialComplexes"
loadPackage "VersalDeformations"

S1 = simplicialComplex {x_1*x_2*x_3, x_1*y_0*x_3, x_3*x_4*y_0,
    x_6*x_1*y_0, x_6*x_4*y_0, x_6*x_5*x_4}
S2 = simplicialComplex {z_1*z_2*z_3, z_1*y_1*z_3, z_3*z_4*y_1,
    z_6*z_1*y_1, z_6*z_4*y_1, z_6*z_5*z_4}
I1 = ideal S1
I2 = ideal S2


R = QQ[first entries vars R1 | first entries vars R2]
I = sub(I1,R) + sub(I2,R)
```

We first create the rings with the necessary variables, then we define the simplicial complexes by their maximal faces. Finally we create the ideal of the join, which is just the sum of the individual ideals.

We can compute T^2:

```
i11 : CT^2(0, gens I);
```

```
                115          76
o11 : Matrix R      <--- R
```

It is 76-dimensional, which is still quite big, but much smaller than if we had used the other triangulation.

We can compute T^1:

```
i13 : T11 = CT^1(0, gens I);

                18          58
o13 : Matrix R     <--- R
```

This is the module of first-order deformations, which is 58-dimensional.

Using the `VersalDeformations` package, we can lift the deformations to second order:

```
(f1,r1,g1,c1) = versalDeformation(gens I, T11, CT^2(0, gens I),
    HighestOrder =>2, Verbose => 10);
```

Then `ideal sum g1` is the second order terms of the obstruction equations of the versal base space. The ideal is generated by 76 elements, and by inspection we see that half of them uses only half of the deformation parameters. This makes it easier to compute a decomposition of it. We do it as follows:

```
loadPackage "Binomials"
IG = ideal sum g1

IG1 = ideal ((IG_*)_{0..37})
IG2 = ideal ((IG_*)_{38..75})

T = QQ[t_1..t_27]
IGT1 = sub(IG1,T)
kList = BPD IGT1

T2 = QQ[t_28..t_58]
IGT2 = ideal mingens sub(IG,T2)
kList2 = BPD IGT2
```

This takes about a minute. We use the package `Binomials`, which decomposes binomial ideals fast. Finally, we put the decomposed parts in the same ring, and make a list of all the components:

```
TT = QQ[t_1..t_58]
kListTT = apply(kList, I -> sub(I,TT))
kList2TT = apply(kList2, I -> sub(I,TT))

intersect(intersect kListTT, intersect(kList2TT)) == IGTT -- long time

comps = apply(toList ((set kListTT) ** (set kList2TT)), S -> ideal mingens (S#0 +S#1));
max apply(comps, dim) -- answer: 44
maxComp = select(comps, I -> dim I == 44)
```

We check which component has the maximal dimension, and it turns out that it has dimension 44. We select that component in the last line. This ideal is generated by a subset of the deformation parameters.

We have been unable to lift this 44-dimensional family, though.

By selecting deformation parameters carefully, we can however find a family whose generic fiber is the ideal J above (the sum of two del Pezzo's). This family is 8-dimensional.

Remark. *This is very promising, because of the following: we have found a smoothing of the singular Calabi-Yau inside Y_0, of which we computed the Euler characteristic to be -72. This fits well with the Batyrev-Borisov calculations above: if the Hodge numbers are $(8, 44)$, we have potentially found an open subset of the moduli space of complex structures of this smoothing. The 8-dimensional subfamily could correspond to the space of complex structures on the mirror.*

4 Singularities

4.1 Of the toric hypersurface

Again consider the join of two hexagons, joined with a single vertex. This is a 4-dimensional simplicial complex, which deforms to the toric variety with polytope with vertices $(v, 0)$ and $(0, v)$, where v are vertices of the hexagon. This is the same toric variety as in "Second example" above.

If `JJ` is the ideal of this toric variety, the following code will compute its singularities.

```
singlist = {}
for i from 1 to 6 do {
    sz = sub(JJ, z_i => 1);
    sx = sub(JJ, x_i => 1);
    singz = radical ideal mingens ideal singularLocus
    minimalPresentation sz;
    singx = radical ideal mingens ideal singularLocus
    minimalPresentation sx;
    singsx = (decompose singx);
    singsz = (decompose singz);
    sings = singsx | singsz;
    invz = sz.cache.minimalPresentationMap;
    invx = sx.cache.minimalPresentationMap;
    singlist = singlist | apply(singsx, I -> homogenize(preimage
    (invx, singx),x_i)) | apply(singsz, I -> homogenize(preimage(
    invz, singz),z_i));
    }
sings = intersect singlist
```

X_P have 48 curves as singularities. Hence a general hyperplane section will have 48 isolated singularities.

Remark. *Local calculations hint that these should be nodal singularities, but I don't immediately know how to see this.*

5 Calabi-Yaus

5.1 Singular in a 5-dimensional toric

Let Y_0 be the toric variety from embedded in $\P^{13}$ by (a subset of) the anticanonical system (use only the vertices and the origin). It is the join of two del Pezzo surfaces. The singular locus is the disjoint union of these del Pezzo surfaces. If we intersect Y_0 with two generic sections of the anticanonical bundle (in other words: two generic sections of $\mathscr{O}_{Y_0}(1)$), we get a Calabi-Yau with isolated singularities.

In fact, local calculations on separate del Pezzos show that we don't need the hyperplanes to be generic. We'd like to have a Calabi-Yau on which a group act, so we want invariant hyperplanes. From Section , we know that $\mathbb{Z}_2 \times \mathbb{Z}_2$ act on each del Pezzo on Y_0. Hence we have a action of $\mathbb{Z}_2^5$ on Y_0, given by permuting each factor, and exchanging the factors.

Remark. *We also have an action of $D_6 \times D_6 \times \mathbb{Z}_2$ on Y_0, but since we want the action to descend to the Calabi-Yau, we'd like invariant hyperplanes.*

However, this group is too big - there is only one invariant hyperplane with respect to this group (the hyperplane with all coefficients equal).

There is a 3-dimensional vector space of invariant hyperplanes from $\mathscr{O}_{Y_0}(1)$. We choose two of them:

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + y_0 + z_1 + z_2 + z_3 + z_4 + z_+5 + z_6 + y_1 = 0$$

and

$$x_1 + x_2 + 2x_3 + x_4 + x_5 + 2x_6 + y_0 + z_1 + z_2 + 2z_3 + z_4 + z_+5 + 2z_6 + y_1 = 0.$$

Local calculations show that this choice of hyperplanes give isolated singularities. They are all of the form $C(dP_6)$ and there are 12 of them. They come in two orbits under the group action: 4 with a $\mathbb{Z}_2$ stabilizer, and 8 with trivial stabilizer. The four with nontrivial stabilizer have coordinates

$$\begin{aligned}
&(x_1 : x_2 : x_3 : x_4 : x_5 : x_6 : y_0 : z_1 : z_2 : z_3 : z_4 : z_5 : z_6 : z_1) \\
&= (0 : 0 : 0 : 1 : -1 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0), \\
&= (1 : -1 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0), \\
&= (0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 0 : 1 : -1 : 0 : 0), \\
&= (0 : 0 : 0 : 0 : 0 : 0 : 0 : 1 : -1 : 0 : 0 : 0 : 0 : 0).
\end{aligned}$$

The other 8 have all nonzero coefficients with irrational coordinates. The exact coordinates can be computed symbolically in Mathematica for example.

The action have two fixed points that are not already singularities. The point P_1 with all cordinates equal to one is fixed. Also, the point P_2 with the first seven coordinates equal to $\lambda \neq 1, 0$, and the last seven equal to 1, is also fixed.

There are several points with nontrivial stabilizer [[find all of these]].

6 Conceptual description

Let E be a rank 3 vector space, and let $\mathbb{P}^{17} = \mathbb{P}(E \otimes E \oplus E \otimes E)$, thought of as the set of 3×3 block matrices. Let M be the set of block matrices having rank two. M decomposes as $M = M' \cup M_1 \cup M_2$, where M_i are the sets of block matrices where one the blocks is zero, and the other has rank 2. M' is the subset of matrices where both blocks have rank exactly 1. The dimensions are 9, 4, 4.

The singular locus of (the closure of) M' is the set of matrices $(0, B)$ and $(A, 0)$, where A, B have rank 1.

If we intersect M with a general 12-plane (of codimension 6), we therefore get a smooth Calabi-Yau X.

Let S_3 act on E by permutations of a chosen basis. Then it act on $E \otimes E$ as well. The group $D_6 \simeq S_3 \times \mathbb{Z}_2$ act on the sum $E \otimes E \oplus E \otimes E$ by exchanging factors.

We choose a plane $H \simeq \mathbb{P}^{11} \subset \mathbb{P}^{17}$ such that G act on it. There are several ways to do this. One way is to start with a generic $v_1 \otimes v_2 + v_3 + v_4$ and let G on this tensor. Since G has order 12, we get 12 vectors (matrices) which span a $\mathbb{P}^{11}$.

To get coordinates, let x_i be coordinates on $\mathbb{P}^{11}$. Let $A = \sum_{i=1}^{12} A_i x_i$. Then X is defined by the **2x2**-minors of this block matrix.

6.1 Map to $(\mathbb{P}^2)^{\times 4}$

There is a map from $M' \setminus \mathrm{Sing}(M)$ to $(\mathbb{P}^2)^4$ given by sending a pair of rank 1 matrices (A, B) to the tensor $v_1 \otimes v_2 \otimes v_3 \otimes v_4$, where $v_1 \otimes v_2 = A$ and $v_3 \otimes v_4 = B$. The map has $\mathbb{A}^1 \setminus pt$-fibers: the inverse image of a point is the line between A and B: $\{tA + sB\}_{(t:s) \in \mathbb{A} \setminus 0}$. Let π be this map.

Since X doesnt intersect the singular locus of M, we get a map $\pi : X \to (\mathbb{P}^2)^4$ by restriction. For generic choice of $\mathbb{P}^{11}$, this map is injective. [[this should give us the Hodge numbers of X]]

6.2 The invariant subfamily

[[the invariant subfamily]]