

# An Interface for using polymake in GAP

( Version 0.7.1 )

**Marc Roeder**

**Marc Roeder** — Email: [marc.roeder\(at\)nuigalway.ie](mailto:marc.roeder@nuigalway.ie)

**Address:** Marc Roeder, Department of Mathematics, NUI  
Galway, Ireland

## Abstract

This package provides a very basic interface to the polymake program by Evgenij Gawrilow, Michael Joswig et al. [GJ]. The polymake program itself is not included.

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# Contents

<b>1</b>	<b>Installation and Preface</b>	<b>5</b>
1.1	A few words about the installation of polymake . . . . .	5
1.2	Setting variables for external programs . . . . .	5
1.2.1	SetPolymakeDataDirectory . . . . .	5
1.2.2	SetPolymakeCommand . . . . .	6
1.2.3	Setting variables permanently . . . . .	6
<b>2</b>	<b>Polymake interaction</b>	<b>7</b>
2.1	Creating Polymake Objects . . . . .	7
2.1.1	CreateEmptyFile . . . . .	7
2.1.2	CreatePolymakeObject . . . . .	7
2.1.3	CreatePolymakeObjectFromFile . . . . .	7
2.2	Accessing Properties of Polymake Objects . . . . .	8
2.2.1	DirectoryOfPolymakeObject . . . . .	8
2.2.2	FilenameOfPolymakeObject . . . . .	8
2.2.3	FullFilenameOfPolymakeObject . . . . .	8
2.2.4	NamesKnownPropertiesOfPolymakeObject . . . . .	8
2.2.5	KnownPropertiesOfPolymakeObject . . . . .	8
2.2.6	PropertyOfPolymakeObject . . . . .	9
2.3	Example: Creating and Accessing Polymake Objects . . . . .	9
2.4	Writing to Polymake Objects . . . . .	9
2.4.1	AppendToPolymakeObject . . . . .	9
2.4.2	AppendPointlistToPolymakeObject . . . . .	10
2.4.3	AppendVertexlistToPolymakeObject . . . . .	10
2.4.4	AppendInequalitiesToPolymakeObject . . . . .	10
2.4.5	ConvertMatrixToPolymakeString . . . . .	10
2.4.6	ClearPolymakeObject . . . . .	10
2.4.7	WriteKnownPropertyToPolymakeObject . . . . .	11
2.4.8	UnbindKnownPropertyOfPolymakeObject . . . . .	11
2.5	Calling Polymake and converting its output . . . . .	11
2.5.1	Polymake . . . . .	11
2.6	An Example . . . . .	11
<b>3</b>	<b>Global Variables</b>	<b>13</b>
3.1	An InfoClass for debug purpose . . . . .	13
3.1.1	InfoPolymaking . . . . .	13

3.2	Variables for system interaction . . . . .	13
3.2.1	POLYMAKE_COMMAND . . . . .	13
3.2.2	POLYMAKE_DATA_DIR . . . . .	13
<b>4</b>	<b>Converting Polymake Output</b>	<b>14</b>
4.1	The General Method . . . . .	14
4.1.1	Converter- Philosophy . . . . .	14
4.1.2	ConvertPolymakeOutputToGapNotation . . . . .	14
4.1.3	SplitPolymakeOutputStringIntoBlocks . . . . .	15
4.1.4	ObjectConverters . . . . .	15
4.2	Conversion Functions . . . . .	15
4.2.1	ConvertPolymakeNumber . . . . .	15
4.2.2	ConvertPolymakeScalarToGAP . . . . .	15
4.2.3	ConvertPolymakeMatrixToGAP . . . . .	15
4.2.4	ConvertPolymakeVectorToGAP . . . . .	16
4.2.5	ConvertPolymakeBoolToGAP . . . . .	16
4.2.6	ConvertPolymakeSetToGAP . . . . .	16
4.2.7	ConvertPolymakeGraphToGAP . . . . .	16
4.2.8	ConvertPolymakeHasseDiagramToGAP . . . . .	16

# Chapter 1

## Installation and Preface

To install the package, just unpack it in your packages directory (usually `~/gap/pkg` for local installation). To use polymaking, you need a working installation of the program `polymake` <http://www.math.tu-berlin.de/polymake/>. The package has been tested on linux and Mac OS X (10.4 and 10.5). But it should be as platform independent as GAP and `polymake`.

The interaction with `polymake` is restricted to writing files and carrying out simple operations looking like

```
polymake file KEYWORD1 KEYWORD2 KEYWORD3
```

on the command line. Using multiple files in one command is not supported as are scripts. Also, there is no direct interface to any of the `polymake` clients (like `intersction`).

### 1.1 A few words about the installation of `polymake`

polymaking will try to guess the location of `polymake`. If this fails, a warning is issued at load time (InfoWarning level 1). Note that the guessing procedure is suppressed when `POLYMAKE_COMMAND` (3.2.1) is set manually (see 1.2.3).

Note that `polymake` calls other external functions ("clients") to do some work for it. These functions must be either in the path from which GAP was called or in a path listed in the `PATH` environment variable. You can set it using the shell command

```
setenv PATH ${PATH}:<your polymakepath>
```

The general rule is: If polymaking finds `polymake` by itself, there is nothing to worry about.

### 1.2 Setting variables for external programs

As polymaking uses the program `polymake`, it needs to know where this program lives. The communication with `polymake` is done by writing files for `polymake` and reading its output (as returned to standard output "the prompt"). Note that the interface does not read any `polymake` file.

#### 1.2.1 SetPolymakeDataDirectory

◇ `SetPolymakeDataDirectory(dir)`

(method)

Sets the directory in which all polymake files are created to *dir*. The standard place for these files is a temporary directory generated when the package is loaded. This manipulates POLYMAKE\_DATA\_DIR (3.2.2).

### 1.2.2 SetPolymakeCommand

◇ SetPolymakeCommand(*command*) (method)

Sets the name for the polymake program to *command*. This manipulates POLYMAKE\_COMMAND (3.2.1).

### 1.2.3 Setting variables permanently

To permanently set the values of POLYMAKE\_COMMAND (3.2.1) and POLYMAKE\_DATA\_DIR (3.2.2), add the lines

```
POLYMAKE_DATA_DIR:=Directory("/home/mypolymakedatadir");  
POLYMAKE_COMMAND:=Filename(Directory("/home/mypolymakebindir/"), "polymake");
```

to your .gaprc file (see **Reference: The .gaprc file**). Note that these have to be *before* the LoadPackage("polymaking"); line. Or you can change the values of the above variables by editing lib/environment.gi

## Chapter 2

# Polymake interaction

### 2.1 Creating Polymake Objects

The interaction with the polymake program is done via files. So a `PolymakeObject` is mainly a pointer to a file and a list of known properties of the object. These properties need not be stored in the file. Whenever polymake is called, the returned value is read from standard output and stored in the `PolymakeObject` corresponding to the file for which polymake is called.

#### 2.1.1 CreateEmptyFile

◇ `CreateEmptyFile(filename)` (method)

**Returns:** nothing

Creates an empty file with name *filename*. Note that *filename* has to include the full path and the directory for the file must exist.

#### 2.1.2 CreatePolymakeObject

◇ `CreatePolymakeObject()` (method)

◇ `CreatePolymakeObject(dir)` (method)

◇ `CreatePolymakeObject(prefix, dir)` (method)

**Returns:** `PolymakeObject`

If called without arguments, this method generates an empty file in the directory defined by `POLYMAKE_DATA_DIR` (3.2.2). If a directory *dir* is given (this directory must exist), an empty file is generated in this directory. If *prefix* is not given, the file is called `polyN` where N is the current runtime. If a file of this name already exists, a number is appended separated by a dot (example: "poly1340" and "poly1340.1"). If *prefix* is given, the filename starts with that prefix.

#### 2.1.3 CreatePolymakeObjectFromFile

◇ `CreatePolymakeObjectFromFile(filename)` (method)

◇ `CreatePolymakeObjectFromFile(dir, filename)` (method)

**Returns:** `PolymakeObject`

This method generates a `PolymakeObject` corresponding to the file *filename* in the directory *dir*. If *dir* is not given, the `POLYMAKE_DATA_DIR` is used. If no file with name *filename* exists in *dir* (or `POLYMAKE_DATA_DIR`, respectively), an empty file is created. Note that the contents of

the file do not matter for the generation of the object. In particular, the object does not know any of the properties that might be encoded in the file. The only way to transfer information from files to `PolymakeObject`s is via `Polymake` (2.5.1).

## 2.2 Accessing Properties of Polymake Objects

A `PolymakeObject` contains information about the directory of its file, the name of its file and about properties calculated by calling `Polymake` (2.5.1). The properties returned by the `polymake` program are stored under the name `polymake` assigns to them (that is, the name of the data block in the corresponding file). The following methods can be used to access the information stored in a `PolymakeObject`. But be careful! All functions return the actual object. No copies are made. So if you change one of the returned objects, you change the `PolymakeObject` itself.

### 2.2.1 DirectoryOfPolymakeObject

◇ `DirectoryOfPolymakeObject (poly)` (method)  
**Returns:** Directory  
 Returns the directory of the file associated with `poly`.

### 2.2.2 FilenameOfPolymakeObject

◇ `FilenameOfPolymakeObject (poly)` (method)  
**Returns:** String  
 Returns the name of the file associated with `poly`. This does only mean the name of the *file*, not the full path. For the full path and file name see `FullFilenameOfPolymakeObject` (2.2.3)

### 2.2.3 FullFilenameOfPolymakeObject

◇ `FullFilenameOfPolymakeObject (poly)` (method)  
**Returns:** String  
 Returns the file associated with the `PolymakeObject` `poly` with its complete path.

### 2.2.4 NamesKnownPropertiesOfPolymakeObject

◇ `NamesKnownPropertiesOfPolymakeObject (poly)` (method)  
**Returns:** List of Strings  
 Returns a list of the names of all known properties. This does only include the properties returned by `Polymake` (2.5.1), "dir" and "filename" are not included. If no properties are known, fail is returned.

### 2.2.5 KnownPropertiesOfPolymakeObject

◇ `KnownPropertiesOfPolymakeObject (poly)` (method)  
**Returns:** Record  
 Returns the record of all known properties. If no properties are known, fail is returned.

### 2.2.6 PropertyOfPolymakeObject

◇ `PropertyOfPolymakeObject(poly, name)` (method)

Returns the value of the property *name* if it is known. If the value is not known, *fail* is returned. *name* must be a String.

## 2.3 Example: Creating and Accessing Polymake Objects

Suppose the file `/tmp/threecube.poly` contains the three dimensional cube in polymake form (as generated by the command line `cube /tmp/threecube.poly 3 1`). Now generate a `PolymakeObject` from this file and call `Polymake` (2.5.1) to make the vertices of the cube known to the object.

Example

```
### suppose we have a polymake file /tmp/threecube.poly
### containing a cube in three dimensions
gap> cube:=CreatePolymakeObjectFromFile(Directory("/tmp"),"threecube.poly");
<polymake object. No properties known>
gap> FilenameOfPolymakeObject(cube);
"threecube.poly"
gap> FullFilenameOfPolymakeObject(cube);
"/tmp/threecube.poly"
#nothing is known about the cube:
gap> NamesKnownPropertiesOfPolymakeObject(cube);
fail
gap> Polymake(cube,"VERTICES");
[ [-1, -1, -1 ], [ 1, -1, -1 ], [-1, 1, -1 ], [ 1, 1, -1 ], [-1, -1, 1 ],
  [ 1, -1, 1 ], [-1, 1, 1 ], [ 1, 1, 1 ] ]
# Now <cube> knows its vertices:
gap> Print(cube);
<polymake object threecube.poly. Properties known: [ "VERTICES" ]>
gap> PropertyOfPolymakeObject(cube,"VERTICES");
[ [-1, -1, -1 ], [ 1, -1, -1 ], [-1, 1, -1 ], [ 1, 1, -1 ], [-1, -1, 1 ],
  [ 1, -1, 1 ], [-1, 1, 1 ], [ 1, 1, 1 ] ]
gap> KnownPropertiesOfPolymakeObject(cube);
rec(
  VERTICES := [ [-1, -1, -1 ], [ 1, -1, -1 ], [-1, 1, -1 ], [ 1, 1, -1 ],
    [-1, -1, 1 ], [ 1, -1, 1 ], [-1, 1, 1 ], [ 1, 1, 1 ] ] )
```

## 2.4 Writing to Polymake Objects

To transfer data from GAP to polymake, the following methods can be used. But bear in mind that none of these functions test if the resulting polymake file is still consistent.

### 2.4.1 AppendToPolymakeObject

◇ `AppendToPolymakeObject(poly, string)` (method)

**Returns:** nothing

This appends the string *string* to the file associated to the `PolymakeObject` *poly*. It is not tested if the string is syntactically correct as a part of a *polymake* file. It is also not tested if the string is compatible with the data already contained in the file.

INEQUALITIES, POINTS and VERTICES can be appended to a *polymake* object using the following functions:

### 2.4.2 AppendPointlistToPolymakeObject

◇ `AppendPointlistToPolymakeObject(poly, pointlist)` (method)

**Returns:** nothing

Takes a list *pointlist* of vectors and converts it into a string which represents a *polymake* block labeled "POINTS". This string is then added to the file associated with *poly*. The "POINTS" block of the file associated with *poly* then contains points with leading ones, as *polymake* uses affine notation.

### 2.4.3 AppendVertexlistToPolymakeObject

◇ `AppendVertexlistToPolymakeObject(poly, pointlist)` (method)

**Returns:** nothing

Does the same as `AppendPointlistToPolymakeObject`, but with "VERTICES" instead of "POINTS".

### 2.4.4 AppendInequalitiesToPolymakeObject

◇ `AppendInequalitiesToPolymakeObject(poly, ineqlist)` (method)

**Returns:** nothing

Just appends the inequalities given in *ineqlist* to the *polymake* object *poly* (with caption "INEQUALITIES"). Note that this does not check if an "INEQUALITIES" section does already exist in the file associated with *poly*.

### 2.4.5 ConvertMatrixToPolymakeString

◇ `ConvertMatrixToPolymakeString(name, matrix)` (method)

**Returns:** String

This function takes a matrix *matrix* and converts it to a string. This string can then be appended to a *polymake* file via `AppendToPolymakeObject` (2.4.1) to form a block of data labeled *name*. This may be used to write blocks like INEQUALITIES or FACETS.

### 2.4.6 ClearPolymakeObject

◇ `ClearPolymakeObject(poly)` (method)

**Returns:** nothing

Deletes all known properties of the `PolymakeObject` *poly* and replaces its file with an empty one.

There are also methods to manipulate the known values without touching the file of the `PolymakeObject`:

### 2.4.7 WriteKnownPropertyToPolymakeObject

◇ `WriteKnownPropertyToPolymakeObject(poly, name, data)` (method)

Takes the object *data* and writes it to the known properties section of the `PolymakeObject` *poly*. The string *name* is used as the name of the property. If a property with that name already exists, it is overwritten. Again, there is no check if *data* is consistent, correct or meaningful.

### 2.4.8 UnbindKnownPropertyOfPolymakeObject

◇ `UnbindKnownPropertyOfPolymakeObject(poly, name)` (method)

If the `PolymakeObject` *poly* has a property with name *name*, that property is unbound. If there is no such property, `fail` is returned.

## 2.5 Calling Polymake and converting its output

### 2.5.1 Polymake

◇ `Polymake(polyoption [, :[, PolymakeNolookup]])` (method)

This method calls the `polymake` program (see `POLYMAKE_COMMAND` (3.2.1)) with the option *option*. You may use several keywords such as "DIM VERTICES" as an option. The returned value is cut into blocks starting with keywords (which are taken from output and not looked up in *option*). Each block is then interpreted and translated into GAP readable form. This translation is done using the functions given in `ObjectConverters` (4.1.4). The first line of each block of `polymake` output is taken as a keyword and the according entry in `ObjectConverters` (4.1.4) is called to convert the block into GAP readable form. If no such conversion function exists, an error is issued. If only one keyword has been given as *option*, `Polymake` returns the result of the conversion operation. If more than one keyword has been given or the output consists of more than one block, `Polymake` returns `fail`. In any case, the calculated values for each block are stored as known properties of the `PolymakeObject` *poly* as long as they are not `fail`. If `Polymake` is called with an option that corresponds to a name of a known property of *poly*, the known property is returned. In this case, there is no call of the external program. (see below for suppression of this feature).

Note that the command `Polymake` returns `fail` if nothing is returned by the program `polymake` or more than one block of data is returned. For example, the returned value of `Polymake(poly, "VISUAL")` is always `fail`. Likewise, `Polymake(poly, "POINTS VERTICES")` will return `fail` (but may add new known properties to *poly*). For a description of the conversion functions, see chapter 4.

If the option `PolymakeNolookup` is set to anything else than `false`, the `polymake` program is called even if *poly* already has a known property with name *option*.

## 2.6 An Example

Let's generate a three dimensional permutahedron.

Example

```
gap> S:=SymmetricGroup(3);
```

```
Sym( [ 1 .. 3 ] )
gap> v:=[1,2,3];
[ 1, 2, 3 ]
gap> points:=Orbit(S,v,Permuted);;
gap> permutahedron:=CreatePolymakeObject();
<polymake object. No properties known>
gap> AppendPointlistToPolymakeObject(permutahedron,points);
gap> Polymake(permutahedron,"VOLUME");
3
gap> Polymake(permutahedron,"N_VERTICES");
6
    #Now <permutahedron> knows its number of vertices, but not the vertices:
gap> PropertyOfPolymakeObject(permutahedron,"VERTICES");
fail
gap> NamesKnownPropertiesOfPolymakeObject(permutahedron);
[ "VOLUME", "N_VERTICES" ]
    #Let's look at the object!
gap> Polymake(permutahedron,"VISUAL");
#I There was no or wrong polymake output
fail
gap> Polymake(permutahedron,"DIM");
2
```

## Chapter 3

# Global Variables

### 3.1 An InfoClass for debug purpose

#### 3.1.1 InfoPolymaking

◇ InfoPolymaking (info class)

If set to at least 2, the output of polymake is shown. At level 1, warnings are shown. This is the default. And at level 0, the polymake package remains silent.

### 3.2 Variables for system interaction

The variables for interaction with the system are contained in the file `environment.gi`. Each of these variables has a function to set it, see 1.2. If `POLYMAKE_COMMAND` or `POLYMAKE_DATA_DIR` are set at startup, they are not overwritten. So if you don't want (or don't have the rights) to modify `environment.gi`, you can set the variables in your `.gaprc` file.

#### 3.2.1 POLYMAKE\_COMMAND

◇ POLYMAKE\_COMMAND (global variable)

This variable should contain the name of the polymake program in the form as returned by `Filename`. So a probable value is `Filename(Directory("/usr/local/bin"), "polymake")`.

#### 3.2.2 POLYMAKE\_DATA\_DIR

◇ POLYMAKE\_DATA\_DIR (global variable)

In this directory the files for polymake will be created. By default, this generates a temporary directory using `DirectoryTemporary`

## Chapter 4

# Converting Polymake Output

### 4.1 The General Method

When `polymake` is called, its output is read as a string and then processed as follows:

1. the lines containing upper case letters are found. These are treated as lines containing the keywords. Each of those lines marks the beginning of a block of data.
2. The string is then cut into a list of blocks (also strings). Each block starts with a line containing the keyword and continues with some lines of data.
3. for each of the blocks, the appropriate function of `ObjectConverters` is called. Here "appropriate" just means, that the keyword of the block coincides with the name of the function.
4. The output of the conversion function is then added to the known properties of the `PolymakeObject` for which `Polymake` was called.

#### 4.1.1 Converter- Philosophy

The converter functions should take meaningful `polymake` data into meaningful GAP data. This sometimes means that the (mathematical) representation is changed. Here is an example: `polymake` writes vectors as augmented affine vectors of the form  $1 \ a_1 \ a_2 \ a_3 \dots$  which does not go very well with the usual GAP conventions of column vectors and multiplying matrices from the right. So `polymake` converts such a vector to  $[a_1, a_2, a_3, \dots]$  and the user is left with the problem of augmentation and left or right multiplication.

*Call for help:* As of version 0.7.0, most of the converters were assigned blindly to keywords. So some of them might not be suitable. If you find one of those, please tell me about it. Also, for a lot of keywords and data types, there is no converter. Please tell me if you want a new converter.

The conversion process is done by the following methods:

#### 4.1.2 ConvertPolymakeOutputToGapNotation

◇ `ConvertPolymakeOutputToGapNotation(string)` (method)

**Returns:** Record having `polymake` keywords as entry names and the respective converted `polymake` output as entries.

Given a the output of the `polymake` program as a string `string`, this method first calls `SplitPolymakeOutputStringIntoBlocks` (4.1.3). For each of the returned blocks, the name

(=first line) of the block is read and the record `ObjectConverters` (4.1.4) is looked up for an entry with that name. If such an entry exists, it (being a function!) is called and passed the block. The returned value is then given the name of the block and added to the record returned by `ConvertPolymakeOutputToGapNotation`.

### 4.1.3 SplitPolymakeOutputStringIntoBlocks

◇ `SplitPolymakeOutputStringIntoBlocks(string)` (method)

**Returns:** List of strings – “blocks”–

The string *string* is cut at the lines starting with an upper case letter. The parts are returned as a list of strings. The initial string *string* remains unchanged.

### 4.1.4 ObjectConverters

◇ `ObjectConverters` (global variable)

The entries of this record are labeled by *polymake* keywords. Each of the entries is a function which converts a string returned by *polymake* to GAP format. So far, only a few converters are implemented. To see which, try `RecNames(ObjectConverters)`;

You can define new converters using the basic functions described in section 4.2.

## 4.2 Conversion Functions

The following functions are used for the functions in `ObjectConverters` (4.1.4).

### 4.2.1 ConvertPolymakeNumber

◇ `ConvertPolymakeNumber(string)` (method)

The string *string* is converted to a rational number. Unlike `Rat`, it tests, if the number represented by *string* is a floating point number and converts it correctly. If this is the case, a warning is issued.

### 4.2.2 ConvertPolymakeScalarToGAP

◇ `ConvertPolymakeScalarToGAP(list)` (method)

If *list* contains a single string, this string is converted into a number using `ConvertPolymakeNumber` (4.2.1).

### 4.2.3 ConvertPolymakeMatrixToGAP

◇ `ConvertPolymakeMatrixToGAP(list)` (method)

◇ `ConvertPolymakeMatrixToGAPKillOnes(list)` (method)

The list *list* of strings is interpreted as a list of row vectors and converted into a matrix. The “KillOnes” version removes the leading ones.

#### 4.2.4 ConvertPolymakeVectorToGAP

- ◇ `ConvertPolymakeVectorToGAP(list)` (method)
- ◇ `ConvertPolymakeVectorToGAPKillOne(list)` (method)

As the corresponding "Matrix" version. Just for vectors.

#### 4.2.5 ConvertPolymakeBoolToGAP

- ◇ `ConvertPolymakeBoolToGAP(list)` (method)

If `list` contains a single string, which is either 0 or 1, this function returns `false` or `true`, respectively.

#### 4.2.6 ConvertPolymakeSetToGAP

- ◇ `ConvertPolymakeSetToGAP(list)` (method)

Let `list` be a list containing single string, which is a list of numbers separated by whitespaces and enclosed by { and }. The returned value is then a set of rational numbers (in the GAP sense).

#### 4.2.7 ConvertPolymakeGraphToGAP

- ◇ `ConvertPolymakeGraphToGAP(list)` (method)

Let `list` be a list of strings representing sets (that is, a list of integers enclosed by { and }). Then a record is returned containing two sets named `.vertices` and `.edges`.

#### 4.2.8 ConvertPolymakeHasseDiagramToGAP

- ◇ `ConvertPolymakeHasseDiagramToGAP(list)` (method)

**Returns:** List of sets of triples (of sets). The returned list is completely immutable.

If `list` is a list of strings as output by `polymake`'s `HASSE_DIAGRAM` algorithm, then this function returns a list of sets.

The  $i$ th entry represents the faces of dimension  $i$ . There is one entry for each dimension between 0 and the dimension of the polyhedron. Note that the last entry consists of a list with exactly one entry representing the whole polyhedron.

Every face is a list with three entries `[vertices, invboundary, boundary]` where `vertices` is a list of integers representing the vertices of the face (and the number of such a vertex is that of the vertex as a vertex of the full polyhedron). The second entry is a list of integers representing the positions of the  $i + 1$  faces containing the current face (in the  $i + 1$ st entry of the Hasse diagram). And the last entry is the list of  $i - 1$  faces containing the current face (numbered by position in the  $i - 1$ st entry in the Hasse diagram). The faces with empty third entry are exactly the vertices while the face with empty second entry is the face corresponding to the whole polyhedron.

The way `polymake` returns Hasse diagrams and vertices makes sure that the numbering of vertices is the same for the output of `HASSE_DIAGRAM` and `VERTICES` (i.e. the  $i$ th vertex of the vertex list is at position  $i$  in the first entry of the Hasse diagram).

# References

[GJ] Ewgenij Gawrilow and Michael Joswig. polymake. <http://www.math.tu-berlin.de/polymake/>. 2

# Index

AppendInequalitiesToPolymakeObject, 10  
AppendPointlistToPolymakeObject, 10  
AppendToPolymakeObject, 9  
AppendVertexlistToPolymakeObject, 10  
  
ClearPolymakeObject, 10  
ConvertMatrixToPolymakeString, 10  
ConvertPolymakeBoolToGAP, 16  
ConvertPolymakeGraphToGAP, 16  
ConvertPolymakeHasseDiagramToGAP, 16  
ConvertPolymakeMatrixToGAP, 15  
ConvertPolymakeMatrixToGAPKillOnes, 15  
ConvertPolymakeNumber, 15  
ConvertPolymakeOutputToGapNotation, 14  
ConvertPolymakeScalarToGAP, 15  
ConvertPolymakeSetToGAP, 16  
ConvertPolymakeVectorToGAP, 16  
ConvertPolymakeVectorToGAPKillOne, 16  
CreateEmptyFile, 7  
CreatePolymakeObject, 7  
CreatePolymakeObjectFromFile, 7  
  
DirectoryOfPolymakeObject, 8  
  
FilenameOfPolymakeObject, 8  
FullFilenameOfPolymakeObject, 8  
  
InfoPolymaking, 13  
  
KnownPropertiesOfPolymakeObject, 8  
  
NamesKnownPropertiesOfPolymakeObject, 8  
  
ObjectConverters, 15  
  
Polymake, 11  
POLYMAKE\_COMMAND, 13  
POLYMAKE\_DATA\_DIR, 13  
PropertyOfPolymakeObject, 9  
  
SetPolymakeCommand, 6  
SetPolymakeDataDirectory, 5  
SplitPolymakeOutputStringIntoBlocks, 15  
UnbindKnownPropertyOfPolymakeObject, 11  
WriteKnownPropertyToPolymakeObject, 11