

NormalizInterface

GAP wrapper for Normaliz

1.5.1

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Chapter 1

Introduction

1.1 What is the purpose of the this package?

Normaliz [BIRS18] is a software for computations with rational cones and affine monoids. It pursues two main computational goals: finding the Hilbert basis, a minimal generating system of the monoid of lattice points of a cone; and counting elements degree-wise in a generating function, the Hilbert series. As a recent extension, Normaliz can handle unbounded polyhedra. The Hilbert basis computation can be considered as solving a linear diophantine system of inhomogeneous equations, inequalities and congruences.

This package encapsulates a libnormaliz cone and gives access to it in the GAP environment. In this way GAP can be used as interactive interface to libnormaliz.

Chapter 2

Functions

In this chapter we describe the functions offered by *NormalizInterface*. All functions supplied by this package start with “Nmz”. For examples see the chapter ‘[Examples](#)’.

2.1 Create a NmzCone

To create a cone object use NmzCone ([2.1.1](#)).

2.1.1 NmzCone

▷ NmzCone(*list*) (function)
Returns: NmzCone

Creates a NmzCone. The *list* argument should contain an even number of elements, alternating between a string and a integer matrix. The string has to correspond to a Normaliz input type string and the following matrix will be interpreted as input of that type.

See the Normaliz manual for the Normaliz version loaded by your version of NormalizInterface for a detailed description of which input type strings are supported and what arguments they take.

Example

```
gap> cone := NmzCone(["integral_closure", [[2,1],[1,3]]]);  
<a Normaliz cone>
```

2.2 Use a NmzCone

2.2.1 NmzHasConeProperty

▷ NmzHasConeProperty(*cone*, *property*) (function)
Returns: whether the cone has already computed the given property
See NmzConeProperty ([2.2.6](#)) for a list of recognized properties.

Example

```
gap> NmzHasConeProperty(cone, "ExtremeRays");  
false
```

2.2.2 NmzKnownConeProperties

▷ NmzKnownConeProperties(*cone*) (function)

Returns: a list of strings representing the known (computed) cone properties

Given a Normaliz cone object, return a list of all properties already computed for the cone.

Example

```
NmzKnownConeProperties(cone);
[ ]
```

2.2.3 NmzSetVerboseDefault

▷ NmzSetVerboseDefault(*verboseFlag*) (function)

Returns: the previous verbosity

Set the global default verbosity state in libnormaliz. This will influence all NmzCone created afterwards, but not any existing ones.

See also NmzSetVerbose (2.2.4)

2.2.4 NmzSetVerbose

▷ NmzSetVerbose(*cone*, *verboseFlag*) (function)

Returns: the previous verbosity

Set the verbosity state for a cone.

See also NmzSetVerboseDefault (2.2.3)

2.2.5 NmzCompute

▷ NmzCompute(*cone*[, *propnames*]) (function)

Returns: a boolean indicating success

Start computing properties of the given cone. The first parameter indicates a cone object, the second parameter is either a single string, or a list of strings, which indicate what should be computed.

The single parameter version is equivalent to NmzCone(*cone*, ["DefaultMode"]). See NmzConeProperty (2.2.6) for a list of recognized properties.

Example

```
gap> NmzHasConeProperty(cone, "SupportHyperplanes");
false
gap> NmzCompute(cone, ["SupportHyperplanes", "IsPointed"]);
true
gap> NmzKnownConeProperties(cone);
[ "EmbeddingDim", "ExtremeRays", "Generators", "InternalIndex",
  "IsDeg1ExtremeRays", "IsInhomogeneous", "IsPointed", "MaximalSubspace",
  "OriginalMonoidGenerators", "Rank", "Sublattice", "SupportHyperplanes" ]
gap> NmzCompute(cone);
gap> NmzKnownConeProperties(cone);
[ "ClassGroup", "EmbeddingDim", "ExtremeRays", "Generators", "HilbertBasis",
  "InternalIndex", "IsDeg1ExtremeRays", "IsInhomogeneous",
  "IsIntegrallyClosed", "IsPointed", "IsTriangulationNested",
  "IsTriangulationPartial", "MaximalSubspace", "OriginalMonoidGenerators",
  "Rank", "Sublattice", "SupportHyperplanes", "TriangulationDetSum",
  "TriangulationSize", "UnitGroupIndex" ]
```

2.2.6 NmzConeProperty

▷ NmzConeProperty(*cone*, *property*)

(function)

Returns: the result of the computation, type depends on the property

Triggers the computation of the property of the cone and returns the result. If the property was already known, it is not recomputed. Currently the following strings are recognized as properties:

- Generators see NmzGenerators (2.3.44),
- ExtremeRays see NmzExtremeRays (2.3.37),
- VerticesOfPolyhedron see NmzVerticesOfPolyhedron (2.3.124),
- SupportHyperplanes see NmzSupportHyperplanes (2.3.107),
- TriangulationSize see NmzTriangulationSize (2.3.120),
- TriangulationDetSum see NmzTriangulationDetSum (2.3.119),
- Triangulation see NmzTriangulation (2.3.118),
- Multiplicity see NmzMultiplicity (2.3.75),
- RecessionRank see NmzRecessionRank (2.3.98),
- AffineDim see NmzAffineDim (2.3.1),
- ModuleRank see NmzModuleRank (2.3.74),
- HilbertBasis see NmzHilbertBasis (2.3.49),
- ModuleGenerators see NmzModuleGenerators (2.3.72),
- Deg1Elements see NmzDeg1Elements (2.3.17),
- HilbertSeries see NmzHilbertSeries (2.3.51),
- HilbertQuasiPolynomial see NmzHilbertQuasiPolynomial (2.3.50),
- Grading see NmzGrading (2.3.45),
- IsPointed see NmzIsPointed (2.3.64),
- IsDeg1ExtremeRays see NmzIsDeg1ExtremeRays (2.3.58),
- IsDeg1HilbertBasis see NmzIsDeg1HilbertBasis (2.3.59),
- IsIntegrallyClosed see NmzIsIntegrallyClosed (2.3.63),
- OriginalMonoidGenerators see NmzOriginalMonoidGenerators (2.3.88),
- IsReesPrimary see NmzIsReesPrimary (2.3.65),
- ReesPrimaryMultiplicity see NmzReesPrimaryMultiplicity (2.3.99),
- ExcludedFaces see NmzExcludedFaces (2.3.33),

- Dehomogenization see `NmzDehomogenization` (2.3.18),
- InclusionExclusionData see `NmzInclusionExclusionData` (2.3.53),
- ClassGroup see `NmzClassGroup` (2.3.11),
- ModuleGeneratorsOverOriginalMonoid see `NmzModuleGeneratorsOverOriginalMonoid` (2.3.73),
- Sublattice computes the efficient sublattice and returns a bool signaling whether the computation was successful. Actual data connected to it can be accessed by `NmzRank` (2.3.96), `NmzEquations` (2.3.29), `NmzCongruences` (2.3.14), and `NmzBasisChange` (2.3.130).

Additionally also the following compute options are accepted as property. They modify what and how should be computed, and return True after a successful computation.

- `Approximate` approximate the rational polytope by an integral polytope, currently only useful in combination with `Deg1Elements`.
- `BottomDecomposition` use the best possible triangulation (with respect to the sum of determinants) using the given generators.
- `DefaultMode` try to compute what is possible and do not throw an exception when something cannot be computed.
- `DualMode` deactivates the dual algorithm for the computation of the Hilbert basis and degree 1 elements. Includes `HilbertBasis`, unless `Deg1Elements` is set. Often a good choice if you start from constraints.
- `KeepOrder` forbids to reorder the generators. Blocks `BottomDecomposition`.

All the properties above can be given to `NmzCompute` (2.2.5). There you can combine different properties, e.g. give some properties that you would like to know and add some compute options.

See the Normaliz manual for a detailed description.

2.2.7 NmzPrintConeProperties

▷ `NmzPrintConeProperties(cone)` (function)

Print an overview of all known properties of the given cone, as well as their values.

2.3 Cone properties

2.3.1 NmzAffineDim

▷ `NmzAffineDim(cone)` (function)

Returns: the affine dimension

The affine dimension of the polyhedron in inhomogeneous computations. Its computation is triggered if necessary.

This is an alias for `NmzConeProperty(cone, "AffineDim")`; see `NmzConeProperty` (2.2.6).

2.3.2 NmzAllGeneratorsTriangulation

▷ NmzAllGeneratorsTriangulation(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "AllGeneratorsTriangulation"); see NmzConeProperty (2.2.6).

2.3.3 NmzAmbientAutomorphisms

▷ NmzAmbientAutomorphisms(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "AmbientAutomorphisms"); see NmzConeProperty (2.2.6).

2.3.4 NmzApproximate

▷ NmzApproximate(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Approximate"); see NmzConeProperty (2.2.6).

2.3.5 NmzAutomorphisms

▷ NmzAutomorphisms(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Automorphisms"); see NmzConeProperty (2.2.6).

2.3.6 NmzAxesScaling

▷ NmzAxesScaling(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "AxesScaling"); see NmzConeProperty (2.2.6).

2.3.7 NmzBasicStanleyDec

▷ NmzBasicStanleyDec(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "BasicStanleyDec"); see NmzConeProperty (2.2.6).

2.3.8 NmzBasicTriangulation

▷ NmzBasicTriangulation(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "BasicTriangulation"); see NmzConeProperty (2.2.6).

2.3.9 NmzBigInt

▷ NmzBigInt(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "BigInt"); see NmzConeProperty (2.2.6).

2.3.10 NmzBottomDecomposition

▷ NmzBottomDecomposition(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "BottomDecomposition"); see NmzConeProperty (2.2.6).

2.3.11 NmzClassGroup

▷ NmzClassGroup(*cone*) (function)

Returns: the class group in a special format

A normal affine monoid M has a well-defined divisor class group. It is naturally isomorphic to the divisor class group of $K[M]$ where K is a field (or any unique factorization domain). We represent it as a vector where the first entry is the rank. It is followed by sequence of pairs of entries n, m . Such two entries represent a free cyclic summand $(\mathbb{Z}/n\mathbb{Z})^m$. Not allowed in inhomogeneous computations.

This is an alias for NmzConeProperty(*cone*, "ClassGroup"); see NmzConeProperty (2.2.6).

2.3.12 NmzCombinatorialAutomorphisms

▷ NmzCombinatorialAutomorphisms(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "CombinatorialAutomorphisms"); see NmzConeProperty (2.2.6).

2.3.13 NmzConeDecomposition

▷ NmzConeDecomposition(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "ConeDecomposition"); see NmzConeProperty (2.2.6).

2.3.14 NmzCongruences

▷ NmzCongruences(*cone*) (function)

Returns: a matrix whose rows represent the congruences

The equations, congruences and support hyperplanes together describe the lattice points of the cone.

This is an alias for NmzConeProperty(*cone*, "Congruences"); see NmzConeProperty (2.2.6).

2.3.15 NmzCoveringFace

▷ NmzCoveringFace(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "CoveringFace"); see NmzConeProperty (2.2.6).

2.3.16 NmzDefaultMode

▷ NmzDefaultMode(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "DefaultMode"); see NmzConeProperty (2.2.6).

2.3.17 NmzDeg1Elements

▷ NmzDeg1Elements(*cone*) (function)

Returns: a matrix whose rows are the degree 1 elements

Requires the presence of a grading. Not allowed in inhomogeneous computations.

This is an alias for NmzConeProperty(*cone*, "Deg1Elements"); see NmzConeProperty (2.2.6).

2.3.18 NmzDehomogenization

▷ NmzDehomogenization(*cone*) (function)

Returns: the dehomogenization vector

Only for inhomogeneous computations.

This is an alias for NmzConeProperty(*cone*, "Dehomogenization"); see NmzConeProperty (2.2.6).

2.3.19 NmzDescent

▷ NmzDescent(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Descent"); see NmzConeProperty (2.2.6).

2.3.20 NmzDistributedComp

▷ NmzDistributedComp(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "DistributedComp"); see NmzConeProperty (2.2.6).

2.3.21 NmzDualFVector

▷ NmzDualFVector(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "DualFVector"); see NmzConeProperty (2.2.6).

2.3.22 NmzDualFaceLattice

▷ NmzDualFaceLattice(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "DualFaceLattice"); see NmzConeProperty (2.2.6).

2.3.23 NmzDualIncidence

▷ NmzDualIncidence(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "DualIncidence"); see NmzConeProperty (2.2.6).

2.3.24 NmzDualMode

▷ NmzDualMode(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "DualMode"); see NmzConeProperty (2.2.6).

2.3.25 NmzDynamic

▷ NmzDynamic(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Dynamic"); see NmzConeProperty (2.2.6).

2.3.26 NmzEhrhartQuasiPolynomial

▷ NmzEhrhartQuasiPolynomial(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "EhrhartQuasiPolynomial"); see NmzConeProperty (2.2.6).

2.3.27 NmzEhrhartSeries

▷ NmzEhrhartSeries(*cone*) (function)

Supported in Normaliz $\geq$ 3.5.0.

This is an alias for NmzConeProperty(*cone*, "EhrhartSeries"); see NmzConeProperty (2.2.6).

2.3.28 NmzEmbeddingDimension

▷ NmzEmbeddingDimension(*cone*) (function)

Returns: the embedding dimension of the cone

The embedding dimension is the dimension of the space in which the computation is done. It is the number of components of the output vectors. This value is always known directly after the creation of the cone.

This is an alias for `NmzConeProperty( cone, "EmbeddingDim" );` see `NmzConeProperty` (2.2.6).

2.3.29 NmzEquations

▷ `NmzEquations(cone)` (function)

Returns: a matrix whose rows represent the equations

The equations cut out the linear space generated by the cone. The equations, congruences and support hyperplanes together describe the lattice points of the cone.

This is an alias for `NmzConeProperty( cone, "Equations" );` see `NmzConeProperty` (2.2.6).

2.3.30 NmzEuclideanAutomorphisms

▷ `NmzEuclideanAutomorphisms(cone)` (function)

This is an alias for `NmzConeProperty( cone, "EuclideanAutomorphisms" );` see `NmzConeProperty` (2.2.6).

2.3.31 NmzEuclideanIntegral

▷ `NmzEuclideanIntegral(cone)` (function)

This is an alias for `NmzConeProperty( cone, "EuclideanIntegral" );` see `NmzConeProperty` (2.2.6).

2.3.32 NmzEuclideanVolume

▷ `NmzEuclideanVolume(cone)` (function)

Supported in Normaliz $\geq 3.5.0$.

This is an alias for `NmzConeProperty( cone, "EuclideanVolume" );` see `NmzConeProperty` (2.2.6).

2.3.33 NmzExcludedFaces

▷ `NmzExcludedFaces(cone)` (function)

Returns: a matrix whose rows represent the excluded faces

This is an alias for `NmzConeProperty( cone, "ExcludedFaces" );` see `NmzConeProperty` (2.2.6).

2.3.34 NmzExploitAutomsVectors

▷ `NmzExploitAutomsVectors(cone)` (function)

This is an alias for `NmzConeProperty( cone, "ExploitAutomsVectors" );` see `NmzConeProperty` (2.2.6).

2.3.35 NmzExploitIsosMult

▷ NmzExploitIsosMult(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "ExploitIsosMult"); see NmzConeProperty (2.2.6).

2.3.36 NmzExternalIndex

▷ NmzExternalIndex(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "ExternalIndex"); see NmzConeProperty (2.2.6).

2.3.37 NmzExtremeRays

▷ NmzExtremeRays(*cone*) (function)

Returns: a matrix whose rows are the extreme rays

This is an alias for NmzConeProperty(*cone*, "ExtremeRays"); see NmzConeProperty (2.2.6).

2.3.38 NmzExtremeRaysFloat

▷ NmzExtremeRaysFloat(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "ExtremeRaysFloat"); see NmzConeProperty (2.2.6).

2.3.39 NmzFVector

▷ NmzFVector(*cone*) (function)

Supported in Normaliz $\geq$ 3.7.0.

This is an alias for NmzConeProperty(*cone*, "FVector"); see NmzConeProperty (2.2.6).

2.3.40 NmzFaceLattice

▷ NmzFaceLattice(*cone*) (function)

Supported in Normaliz $\geq$ 3.7.0.

This is an alias for NmzConeProperty(*cone*, "FaceLattice"); see NmzConeProperty (2.2.6).

2.3.41 NmzFixedPrecision

▷ NmzFixedPrecision(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "FixedPrecision"); see NmzConeProperty (2.2.6).

2.3.42 NmzFullConeDynamic

▷ NmzFullConeDynamic(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "FullConeDynamic"); see NmzConeProperty (2.2.6).

2.3.43 NmzGeneratorOfInterior

▷ NmzGeneratorOfInterior(*cone*) (function)

Returns: a vector representing the generator of the interior of *cone*

If *cone* is Gorenstein, this function returns the generator of the interior of *cone*. If *cone* is not Gorenstein, an error is raised.

This is an alias for NmzConeProperty(*cone*, "GeneratorOfInterior"); see NmzConeProperty (2.2.6).

2.3.44 NmzGenerators

▷ NmzGenerators(*cone*) (function)

Returns: a matrix whose rows are the generators of *cone*

This is an alias for NmzConeProperty(*cone*, "Generators"); see NmzConeProperty (2.2.6).

2.3.45 NmzGrading

▷ NmzGrading(*cone*) (function)

Returns: the grading vector

This is an alias for NmzConeProperty(*cone*, "Grading"); see NmzConeProperty (2.2.6).

2.3.46 NmzGradingDenom

▷ NmzGradingDenom(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "GradingDenom"); see NmzConeProperty (2.2.6).

2.3.47 NmzGradingIsPositive

▷ NmzGradingIsPositive(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "GradingIsPositive"); see NmzConeProperty (2.2.6).

2.3.48 NmzHSOP

▷ NmzHSOP(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "HSOP"); see NmzConeProperty (2.2.6).

2.3.49 NmzHilbertBasis

▷ NmzHilbertBasis(*cone*) (function)

Returns: a matrix whose rows are the Hilbert basis elements

This is an alias for NmzConeProperty(*cone*, "HilbertBasis"); see NmzConeProperty (2.2.6).

2.3.50 NmzHilbertQuasiPolynomial

▷ NmzHilbertQuasiPolynomial(*cone*) (function)

Returns: the Hilbert function as a quasipolynomial

The Hilbert function counts the lattice points degree-wise. The result is a quasipolynomial Q , that is, a polynomial with periodic coefficients. It is given as list of polynomials $P_0, \dots, P_{(p-1)}$ such that $Q(i) = P_{(i \bmod p)}(i)$.

This is an alias for NmzConeProperty(*cone*, "HilbertQuasiPolynomial"); see NmzConeProperty (2.2.6).

2.3.51 NmzHilbertSeries

▷ NmzHilbertSeries(*cone*) (function)

Returns: the Hilbert series as rational function

The result consists of a list with two entries. The first is the numerator polynomial. In inhomogeneous computations this can also be a Laurent polynomial. The second list entry represents the denominator. It is a list of pairs $[k_i, l_i]$. Such a pair represents the factor $(1 - t^{k_i})^{l_i}$.

This is an alias for NmzConeProperty(*cone*, "HilbertSeries"); see NmzConeProperty (2.2.6).

2.3.52 NmzIncidence

▷ NmzIncidence(*cone*) (function)

Supported in Normaliz $\geq 3.8.0$.

This is an alias for NmzConeProperty(*cone*, "Incidence"); see NmzConeProperty (2.2.6).

2.3.53 NmzInclusionExclusionData

▷ NmzInclusionExclusionData(*cone*) (function)

Returns: inclusion-exclusion data

List of faces which are internally have been used in the inclusion-exclusion scheme. Given as a list pairs. The first pair entry is a key of generators contained in the face (compare also NmzTriangulation (2.3.118)) and the multiplicity with which it was considered. Only available with excluded faces or strict constraints as input.

This is an alias for NmzConeProperty(*cone*, "InclusionExclusionData"); see NmzConeProperty (2.2.6).

2.3.54 NmzInputAutomorphisms

▷ NmzInputAutomorphisms(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "InputAutomorphisms"); see NmzConeProperty (2.2.6).

2.3.55 NmzIntegerHull

▷ NmzIntegerHull(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "IntegerHull"); see NmzConeProperty (2.2.6).

2.3.56 NmzIntegral

▷ NmzIntegral(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Integral"); see NmzConeProperty (2.2.6).

2.3.57 NmzInternalIndex

▷ NmzInternalIndex(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "InternalIndex"); see NmzConeProperty (2.2.6).

2.3.58 NmzIsDeg1ExtremeRays

▷ NmzIsDeg1ExtremeRays(*cone*) (function)

Returns: true if all extreme rays have degree 1; false otherwise

This is an alias for NmzConeProperty(*cone*, "IsDeg1ExtremeRays"); see NmzConeProperty (2.2.6).

2.3.59 NmzIsDeg1HilbertBasis

▷ NmzIsDeg1HilbertBasis(*cone*) (function)

Returns: true if all Hilbert basis elements have degree 1; false otherwise

This is an alias for NmzConeProperty(*cone*, "IsDeg1HilbertBasis"); see NmzConeProperty (2.2.6).

2.3.60 NmzIsEmptySemiOpen

▷ NmzIsEmptySemiOpen(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "IsEmptySemiOpen"); see NmzConeProperty (2.2.6).

2.3.61 NmzIsGorenstein

▷ NmzIsGorenstein(*cone*) (function)
Returns: whether the cone is Gorenstein
 Returns true if *cone* is Gorenstein, false otherwise.
 This is an alias for NmzConeProperty(*cone*, "IsGorenstein"); see NmzConeProperty (2.2.6).

2.3.62 NmzIsInhomogeneous

▷ NmzIsInhomogeneous(*cone*) (function)
Returns: whether the cone is inhomogeneous
 This value is always known directly after the creation of the cone.
 This is an alias for NmzConeProperty(*cone*, "IsInhomogeneous"); see NmzConeProperty (2.2.6).

2.3.63 NmzIsIntegrallyClosed

▷ NmzIsIntegrallyClosed(*cone*) (function)
Returns: true if the cone is integrally closed; false otherwise
 It is integrally closed when the Hilbert basis is a subset of the original monoid generators. So it is only computable if we have original monoid generators.
 This is an alias for NmzConeProperty(*cone*, "IsIntegrallyClosed"); see NmzConeProperty (2.2.6).

2.3.64 NmzIsPointed

▷ NmzIsPointed(*cone*) (function)
Returns: true if the cone is pointed; false otherwise
 This is an alias for NmzConeProperty(*cone*, "IsPointed"); see NmzConeProperty (2.2.6).

2.3.65 NmzIsReesPrimary

▷ NmzIsReesPrimary(*cone*) (function)
Returns: true if is the monomial ideal is primary to the irrelevant maximal ideal, false otherwise
 Only used with the input type rees_algebra.
 This is an alias for NmzConeProperty(*cone*, "IsReesPrimary"); see NmzConeProperty (2.2.6).

2.3.66 NmzIsTriangulationNested

▷ NmzIsTriangulationNested(*cone*) (function)
 This is an alias for NmzConeProperty(*cone*, "IsTriangulationNested"); see NmzConeProperty (2.2.6).

2.3.67 NmzIsTriangulationPartial

▷ NmzIsTriangulationPartial(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "IsTriangulationPartial"); see NmzConeProperty (2.2.6).

2.3.68 NmzKeepOrder

▷ NmzKeepOrder(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "KeepOrder"); see NmzConeProperty (2.2.6).

2.3.69 NmzLatticePointTriangulation

▷ NmzLatticePointTriangulation(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "LatticePointTriangulation"); see NmzConeProperty (2.2.6).

2.3.70 NmzLatticePoints

▷ NmzLatticePoints(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "LatticePoints"); see NmzConeProperty (2.2.6).

2.3.71 NmzMaximalSubspace

▷ NmzMaximalSubspace(*cone*) (function)

Returns: a matrix whose rows generate the maximale linear subspace

This is an alias for NmzConeProperty(*cone*, "MaximalSubspace"); see NmzConeProperty (2.2.6).

2.3.72 NmzModuleGenerators

▷ NmzModuleGenerators(*cone*) (function)

Returns: a matrix whose rows are the module generators

This is an alias for NmzConeProperty(*cone*, "ModuleGenerators"); see NmzConeProperty (2.2.6).

2.3.73 NmzModuleGeneratorsOverOriginalMonoid

▷ NmzModuleGeneratorsOverOriginalMonoid(*cone*) (function)

Returns: a matrix whose rows are the module generators over the original monoid

A minimal system of generators of the integral closure over the original monoid. Requires the existence of original monoid generators. Not allowed in inhomogeneous computations.

This is an alias for `NmzConeProperty( cone, "ModuleGeneratorsOverOriginalMonoid" );` see `NmzConeProperty` (2.2.6).

2.3.74 NmzModuleRank

▷ `NmzModuleRank(cone)` (function)

Returns: the rank of the module of lattice points in the polyhedron as a module over the recession monoid

Only for inhomogeneous computations.

This is an alias for `NmzConeProperty( cone, "ModuleRank" );` see `NmzConeProperty` (2.2.6).

2.3.75 NmzMultiplicity

▷ `NmzMultiplicity(cone)` (function)

This is an alias for `NmzConeProperty( cone, "Multiplicity" );` see `NmzConeProperty` (2.2.6).

2.3.76 NmzNoBottomDec

▷ `NmzNoBottomDec(cone)` (function)

This is an alias for `NmzConeProperty( cone, "NoBottomDec" );` see `NmzConeProperty` (2.2.6).

2.3.77 NmzNoDescent

▷ `NmzNoDescent(cone)` (function)

This is an alias for `NmzConeProperty( cone, "NoDescent" );` see `NmzConeProperty` (2.2.6).

2.3.78 NmzNoGradingDenom

▷ `NmzNoGradingDenom(cone)` (function)

This is an alias for `NmzConeProperty( cone, "NoGradingDenom" );` see `NmzConeProperty` (2.2.6).

2.3.79 NmzNoLLL

▷ `NmzNoLLL(cone)` (function)

This is an alias for `NmzConeProperty( cone, "NoLLL" );` see `NmzConeProperty` (2.2.6).

2.3.80 NmzNoNestedTri

▷ NmzNoNestedTri(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NoNestedTri"); see NmzConeProperty (2.2.6).

2.3.81 NmzNoPeriodBound

▷ NmzNoPeriodBound(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NoPeriodBound"); see NmzConeProperty (2.2.6).

2.3.82 NmzNoProjection

▷ NmzNoProjection(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NoProjection"); see NmzConeProperty (2.2.6).

2.3.83 NmzNoRelax

▷ NmzNoRelax(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NoRelax"); see NmzConeProperty (2.2.6).

2.3.84 NmzNoSignedDec

▷ NmzNoSignedDec(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NoSignedDec"); see NmzConeProperty (2.2.6).

2.3.85 NmzNoSubdivision

▷ NmzNoSubdivision(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NoSubdivision"); see NmzConeProperty (2.2.6).

2.3.86 NmzNoSymmetrization

▷ NmzNoSymmetrization(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NoSymmetrization"); see NmzConeProperty (2.2.6).

2.3.87 NmzNumberLatticePoints

▷ NmzNumberLatticePoints(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "NumberLatticePoints"); see NmzConeProperty (2.2.6).

2.3.88 NmzOriginalMonoidGenerators

▷ NmzOriginalMonoidGenerators(*cone*) (function)

Returns: a matrix whose rows are the original monoid generators

This is an alias for NmzConeProperty(*cone*, "OriginalMonoidGenerators"); see NmzConeProperty (2.2.6).

2.3.89 NmzPlacingTriangulation

▷ NmzPlacingTriangulation(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "PlacingTriangulation"); see NmzConeProperty (2.2.6).

2.3.90 NmzPrimalMode

▷ NmzPrimalMode(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "PrimalMode"); see NmzConeProperty (2.2.6).

2.3.91 NmzProjectCone

▷ NmzProjectCone(*cone*) (function)

Supported in Normaliz $\geq$ 3.5.0.

This is an alias for NmzConeProperty(*cone*, "ProjectCone"); see NmzConeProperty (2.2.6).

2.3.92 NmzProjection

▷ NmzProjection(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Projection"); see NmzConeProperty (2.2.6).

2.3.93 NmzProjectionFloat

▷ NmzProjectionFloat(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "ProjectionFloat"); see NmzConeProperty (2.2.6).

2.3.94 NmzPullingTriangulation

▷ NmzPullingTriangulation(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "PullingTriangulation"); see NmzConeProperty (2.2.6).

2.3.95 NmzPullingTriangulationInternal

▷ NmzPullingTriangulationInternal(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "PullingTriangulationInternal"); see NmzConeProperty (2.2.6).

2.3.96 NmzRank

▷ NmzRank(*cone*) (function)

Returns: the rank of the cone

This value is the rank of the lattice generated by the lattice points of the cone.

This is an alias for NmzConeProperty(*cone*, "Rank"); see NmzConeProperty (2.2.6).

2.3.97 NmzRationalAutomorphisms

▷ NmzRationalAutomorphisms(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "RationalAutomorphisms"); see NmzConeProperty (2.2.6).

2.3.98 NmzRecessionRank

▷ NmzRecessionRank(*cone*) (function)

Returns: the rank of the recession cone

Only for inhomogeneous computations.

This is an alias for NmzConeProperty(*cone*, "RecessionRank"); see NmzConeProperty (2.2.6).

2.3.99 NmzReesPrimaryMultiplicity

▷ NmzReesPrimaryMultiplicity(*cone*) (function)

the multiplicity of a monomial ideal, provided it is primary to the maximal ideal generated by the indeterminates. Used only with the input type rees_algebra.

This is an alias for NmzConeProperty(*cone*, "ReesPrimaryMultiplicity"); see NmzConeProperty (2.2.6).

2.3.100 NmzRenfVolume

▷ NmzRenfVolume(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "RenfVolume"); see NmzConeProperty (2.2.6).

2.3.101 NmzSignedDec

▷ NmzSignedDec(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "SignedDec"); see NmzConeProperty (2.2.6).

2.3.102 NmzStanleyDec

▷ NmzStanleyDec(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "StanleyDec"); see NmzConeProperty (2.2.6).

2.3.103 NmzStatic

▷ NmzStatic(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Static"); see NmzConeProperty (2.2.6).

2.3.104 NmzStrictIsoTypeCheck

▷ NmzStrictIsoTypeCheck(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "StrictIsoTypeCheck"); see NmzConeProperty (2.2.6).

2.3.105 NmzSublattice

▷ NmzSublattice(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Sublattice"); see NmzConeProperty (2.2.6).

2.3.106 NmzSuppHypsFloat

▷ NmzSuppHypsFloat(*cone*) (function)

Supported in Normaliz $\geq$ 3.5.2.

This is an alias for NmzConeProperty(*cone*, "SuppHypsFloat"); see NmzConeProperty (2.2.6).

2.3.107 NmzSupportHyperplanes

▷ NmzSupportHyperplanes(*cone*) (function)

Returns: a matrix whose rows represent the support hyperplanes

The equations cut out the linear space generated by the cone. The equations, congruences and support hyperplanes together describe the lattice points of the cone.

This is an alias for NmzConeProperty(*cone*, "SupportHyperplanes"); see NmzConeProperty (2.2.6).

2.3.108 NmzSymmetrize

▷ NmzSymmetrize(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "Symmetrize"); see NmzConeProperty (2.2.6).

2.3.109 NmzTestArithOverflowDescent

▷ NmzTestArithOverflowDescent(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "TestArithOverflowDescent"); see NmzConeProperty (2.2.6).

2.3.110 NmzTestArithOverflowDualMode

▷ NmzTestArithOverflowDualMode(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "TestArithOverflowDualMode"); see NmzConeProperty (2.2.6).

2.3.111 NmzTestArithOverflowFullCone

▷ NmzTestArithOverflowFullCone(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "TestArithOverflowFullCone"); see NmzConeProperty (2.2.6).

2.3.112 NmzTestArithOverflowProjAndLift

▷ NmzTestArithOverflowProjAndLift(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "TestArithOverflowProjAndLift"); see NmzConeProperty (2.2.6).

2.3.113 NmzTestLargePyramids

▷ NmzTestLargePyramids(*cone*) (function)

This is an alias for `NmzConeProperty( cone, "TestLargePyramids" );` see `NmzConeProperty` (2.2.6).

2.3.114 NmzTestLibNormaliz

▷ `NmzTestLibNormaliz( cone )` (function)

This is an alias for `NmzConeProperty( cone, "TestLibNormaliz" );` see `NmzConeProperty` (2.2.6).

2.3.115 NmzTestLinearAlgebraGMP

▷ `NmzTestLinearAlgebraGMP( cone )` (function)

This is an alias for `NmzConeProperty( cone, "TestLinearAlgebraGMP" );` see `NmzConeProperty` (2.2.6).

2.3.116 NmzTestSimplexParallel

▷ `NmzTestSimplexParallel( cone )` (function)

This is an alias for `NmzConeProperty( cone, "TestSimplexParallel" );` see `NmzConeProperty` (2.2.6).

2.3.117 NmzTestSmallPyramids

▷ `NmzTestSmallPyramids( cone )` (function)

This is an alias for `NmzConeProperty( cone, "TestSmallPyramids" );` see `NmzConeProperty` (2.2.6).

2.3.118 NmzTriangulation

▷ `NmzTriangulation( cone )` (function)

Returns: the triangulation

This returns a list of the maximal simplicial cones in a triangulation, i.e., a list of cones dividing the cone into simplicial cones. Each cone in the list is represented by a pair. The first entry of such a pair is the key of the simplex, i.e., a list of integers $a_1, \dots, a_n$ referring to the `NmzGenerators` (2.3.44) (counting from 0) which are used in this simplicial cone. The second entry of each pair in the list is the absolute value of the determinant of the generator matrix of the simplicial cone.

This is an alias for `NmzConeProperty( cone, "Triangulation" );` see `NmzConeProperty` (2.2.6).

2.3.119 NmzTriangulationDetSum

▷ `NmzTriangulationDetSum( cone )` (function)

Returns: sum of the absolute values of the determinants of the simplicial cones in the used triangulation

This is an alias for `NmzConeProperty( cone, "TriangulationDetSum" );` see `NmzConeProperty` (2.2.6).

2.3.120 NmzTriangulationSize

▷ `NmzTriangulationSize( cone )` (function)

Returns: the number of simplicial cones in the used triangulation

This is an alias for `NmzConeProperty( cone, "TriangulationSize" );` see `NmzConeProperty` (2.2.6).

2.3.121 NmzUnimodularTriangulation

▷ `NmzUnimodularTriangulation( cone )` (function)

This is an alias for `NmzConeProperty( cone, "UnimodularTriangulation" );` see `NmzConeProperty` (2.2.6).

2.3.122 NmzUnitGroupIndex

▷ `NmzUnitGroupIndex( cone )` (function)

This is an alias for `NmzConeProperty( cone, "UnitGroupIndex" );` see `NmzConeProperty` (2.2.6).

2.3.123 NmzVerticesFloat

▷ `NmzVerticesFloat( cone )` (function)

Returns: a matrix whose rows are the vertices of the polyhedron `cone` with float coordinates

The rows of this matrix represent the vertices of `cone`, printed as floats for better readability. The result might be inexact, and should therefore not be used for computations.

This is an alias for `NmzConeProperty( cone, "VerticesFloat" );` see `NmzConeProperty` (2.2.6).

2.3.124 NmzVerticesOfPolyhedron

▷ `NmzVerticesOfPolyhedron( cone )` (function)

Returns: a matrix whose rows are the vertices of the polyhedron

This is an alias for `NmzConeProperty( cone, "VerticesOfPolyhedron" );` see `NmzConeProperty` (2.2.6).

2.3.125 NmzVirtualMultiplicity

▷ `NmzVirtualMultiplicity( cone )` (function)

This is an alias for `NmzConeProperty( cone, "VirtualMultiplicity" );` see `NmzConeProperty` (2.2.6).

2.3.126 NmzVolume

▷ NmzVolume(*cone*) (function)

Supported in Normaliz $\geq 3.5.0$.

This is an alias for NmzConeProperty(*cone*, "Volume"); see NmzConeProperty (2.2.6).

2.3.127 NmzWeightedEhrhartQuasiPolynomial

▷ NmzWeightedEhrhartQuasiPolynomial(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "WeightedEhrhartQuasiPolynomial"); see NmzConeProperty (2.2.6).

2.3.128 NmzWeightedEhrhartSeries

▷ NmzWeightedEhrhartSeries(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "WeightedEhrhartSeries"); see NmzConeProperty (2.2.6).

2.3.129 NmzWitnessNotIntegrallyClosed

▷ NmzWitnessNotIntegrallyClosed(*cone*) (function)

This is an alias for NmzConeProperty(*cone*, "WitnessNotIntegrallyClosed"); see NmzConeProperty (2.2.6).

2.3.130 NmzBasisChange

▷ NmzBasisChange(*cone*) (function)

Returns: a record describing the basis change

The result record *r* has three components: *r*.Embedding, *r*.Projection, and *r*.Annihilator, where the embedding *A* and the projection *B* are matrices, and the annihilator *c* is an integer. They represent the mapping into the effective lattice $\mathbb{Z}^n \rightarrow \mathbb{Z}^r, u \mapsto (uB)/c$ and the inverse operation $\mathbb{Z}^r \rightarrow \mathbb{Z}^n, v \mapsto vA$.

This is part of the cone property “Sublattice”.

Chapter 3

Examples

3.1 Generators

Example

```
gap> C := NmzCone(["integral_closure",[[2,1],[1,3]]]);
<a Normaliz cone>
gap> NmzHasConeProperty(C,"HilbertBasis");
false
gap> NmzHasConeProperty(C,"SupportHyperplanes");
false
gap> NmzConeProperty(C,"HilbertBasis");
[ [ 1, 1 ], [ 1, 2 ], [ 1, 3 ], [ 2, 1 ] ]
gap> NmzHasConeProperty(C,"SupportHyperplanes");
true
gap> NmzConeProperty(C,"SupportHyperplanes");
[ [ -1, 2 ], [ 3, -1 ] ]
```

3.2 System of equations

Example

```
gap> D := NmzCone(["equations",[[1,2,-3]], "grading",[[0,-1,3]]]);
<a Normaliz cone>
gap> NmzCompute(D,["DualMode","HilbertSeries"]);
true
gap> NmzHilbertBasis(D);
[ [ 1, 1, 1 ], [ 0, 3, 2 ], [ 3, 0, 1 ] ]
gap> NmzHilbertSeries(D);
[ t^2-t+1, [ [ 1, 1 ], [ 3, 1 ] ] ]
gap> NmzHasConeProperty(D,"SupportHyperplanes");
true
gap> NmzSupportHyperplanes(D);
[ [ 0, 1, 0 ], [ 1, 0, 0 ] ]
gap> NmzEquations(D);
[ [ 1, 2, -3 ] ]
```

3.3 System of inhomogeneous equations

Example

```
gap> P := NmzCone(["inhom_equations",[[1,2,-3,1]], "grading", [[1,1,1]]);
<a Normaliz cone>
gap> NmzIsInhomogeneous(C);
false
gap> NmzIsInhomogeneous(P);
true
gap> NmzHilbertBasis(P);
[ [ 1, 1, 1, 0 ], [ 3, 0, 1, 0 ], [ 0, 3, 2, 0 ] ]
gap> NmzModuleGenerators(P);
[ [ 0, 1, 1, 1 ], [ 2, 0, 1, 1 ] ]
```

3.4 Combined input

Normaliz also allows the combination of different kinds of input, e.g. multiple constraint types, or additional data like a grading.

Suppose that you have a 3 by 3 “square” of nonnegative integers such that the 3 numbers in all rows, all columns, and both diagonals sum to the same constant M . Sometimes such squares are called magic and M is the magic constant. This leads to a linear system of equations. The magic constant is a natural choice for the grading. Additionally we force here the 4 corner to have even value by adding congruences.

Example

```
gap> Magic3x3even := NmzCone(["equations",
> [ [1, 1, 1, -1, -1, -1, 0, 0, 0],
> [1, 1, 1, 0, 0, 0, -1, -1, -1],
> [0, 1, 1, -1, 0, 0, -1, 0, 0],
> [1, 0, 1, 0, -1, 0, 0, -1, 0],
> [1, 1, 0, 0, 0, -1, 0, 0, -1],
> [0, 1, 1, 0, -1, 0, 0, 0, -1],
> [1, 1, 0, 0, -1, 0, -1, 0, 0] ],
> "congruences",
> [ [1, 0, 0, 0, 0, 0, 0, 0, 0, 2],
> [0, 0, 1, 0, 0, 0, 0, 0, 0, 2],
> [0, 0, 0, 0, 0, 0, 1, 0, 0, 2],
> [0, 0, 0, 0, 0, 0, 0, 0, 1, 2] ],
> "grading",
> [ [1, 1, 1, 0, 0, 0, 0, 0, 0] ] );
<a Normaliz cone>
gap> NmzHilbertBasis(Magic3x3even);
[ [ 0, 4, 2, 4, 2, 0, 2, 0, 4 ], [ 2, 0, 4, 4, 2, 0, 0, 4, 2 ],
[ 2, 2, 2, 2, 2, 2, 2, 2, 2 ], [ 2, 4, 0, 0, 2, 4, 4, 0, 2 ],
[ 4, 0, 2, 0, 2, 4, 2, 4, 0 ], [ 2, 3, 4, 5, 3, 1, 2, 3, 4 ],
[ 2, 5, 2, 3, 3, 3, 4, 1, 4 ], [ 4, 1, 4, 3, 3, 3, 2, 5, 2 ],
[ 4, 3, 2, 1, 3, 5, 4, 3, 2 ] ]
gap> NmzHilbertSeries(Magic3x3even);
[ t^3+3*t^2-t+1, [ [ 1, 1 ], [ 2, 2 ] ] ]
gap> NmzHilbertQuasiPolynomial(Magic3x3even);
[ 1/2*t^2+t+1, 1/2*t^2-1/2 ]
```

3.5 Using the dual mode

For solving systems of equations and inequalities it is often faster to use the dual Normaliz algorithm. We demonstrate how to use it with an inhomogeneous system of equations and inequalities.

The input consists of a system of 8 inhomogeneous equations in $\mathbb{R}^3$. The first row of the matrix M encodes the inequality $8x + 8y + 8z + 7 \geq 0$. Additionally we say that x, y, z should be non-negative by giving the sign vector and use the total degree.

Example

```
gap> M := [
> [ 8, 8, 8, 7 ],
> [ 0, 4, 0, 1 ],
> [ 0, 1, 0, 7 ],
> [ 0, -2, 0, 7 ],
> [ 0, -2, 0, 1 ],
> [ 8, 48, 8, 17 ],
> [ 1, 6, 1, 34 ],
> [ 2, -12, -2, 37 ],
> [ 4, -24, -4, 14 ]
> ];;
gap> D := NmzCone(["inhom_inequalities", M,
>               "signs", [[1,1,1]],
>               "grading", [[1,1,1]]]);
<a Normaliz cone>
gap> NmzCompute(D, ["DualMode", "HilbertBasis", "ModuleGenerators"]);
true
gap> NmzHilbertBasis(D);
[ [ 1, 0, 0, 0 ], [ 1, 0, 1, 0 ] ]
gap> NmzModuleGenerators(D);
[ [ 0, 0, 0, 1 ], [ 0, 0, 1, 1 ], [ 0, 0, 2, 1 ], [ 0, 0, 3, 1 ] ]
```

As result we get the Hilbert basis of the cone of the solutions to the homogeneous system and the module generators which are the base solutions to the inhomogeneous system.

Chapter 4

Installing NormalizInterface

4.1 Compiling

NormalizInterface supports GAP 4.9 or later, and Normaliz 3.5.4 or later.

For technical reasons, installing and using NormalizInterface requires that your version of GAP is compiled in a special way. Specifically, GAP must be compiled against the exact same version of the GMP library as Normaliz. By default, GAP compiles its own version of GMP; however, we cannot use that, as it lacks C++ support, which is required by Normaliz.

Thus as the very first step, please install a version of GMP in your system. On most Linux and BSD distributions, there should be a GMP package available with your system's package manager. On Mac OS X, you can install GMP via Fink, MacPorts or Homebrew.

Next, make sure your GAP installation is compiled against the system wide GMP installation. To do so, switch to the GAP root directory, and enter the following commands:

```
make clean
./configure --with-gmp=PATH/TO/YOUR/GMP
make
```

Next you need to compile a recent version of Normaliz. This requires the presence of several further system software packages, which you install via your system's package manager. At least the following are required:

- curl OR wget for downloading the source code

Once you have installed these, you can build Normaliz by using the `prerequisites.sh` script we provide. It takes a single, optional parameter: the location of the GAP root directory.

```
./prerequisites.sh GAPDIR
```

Once it completed successfully, you can then build NormalizInterface like this:

```
./configure --with-gaproot=GAPDIR
make
```

References

- [BIRS18] W. Bruns, B. Ichim, T. Römer, and C. Söger. Normaliz, a tool for computations in affine monoids, vector configurations, lattice polytopes, and rational cones, Version 3.5.4. <https://www.normaliz.uni-osnabrueck.de>, 2018. 3

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