# PBMath

P. Baillehache

February 18, 2018

## Contents



## Introduction

PBMath is a C library providing mathematical structures and functions.

The `VecFloat` structure and its functions can be used to manipulate vectors of float values.

The `VecShort` structure and its functions can be used to manipulate vectors of short values.

The `MatFloat` structure and its functions can be used to manipulate matrices of float values.

The `Gauss` structure and its functions can be used to get values of the Gauss function and random values distributed accordingly with a Gauss distribution.

The `Smoother` functions can be used to get values of the SmoothStep and SmootherStep functions.

The `EqLinSys` structure and its functions can be used to solve systems of linear equation.

It uses the `PBErr` library.

# 1 Definitions

## 1.1 Vector

### 1.1.1 Distance between two vectors

For `VecShort`:

$$\begin{array}{l} Dist(\overrightarrow{v}, \overrightarrow{w}) = \sum_i |v_i - w_i| \\ HamiltonDist(\overrightarrow{v}, \overrightarrow{w}) = \sum_i |v_i - w_i| \\ PixelDist(\overrightarrow{v}, \overrightarrow{w}) = \sum_i |v_i - w_i| \end{array} \quad (1)$$

For `VecFloat`:

$$\begin{array}{l} Dist(\overrightarrow{v}, \overrightarrow{w}) = \sum_i (v_i - w_i)^2 \\ HamiltonDist(\overrightarrow{v}, \overrightarrow{w}) = \sum_i |v_i - w_i| \\ PixelDist(\overrightarrow{v}, \overrightarrow{w}) = \sum_i ||\lfloor v_i \rfloor - \lfloor w_i \rfloor| \end{array} \quad (2)$$

### 1.1.2 Angle between two vectors

The problem is as follow: given two vectors $\vec{V}$ and $\vec{W}$ not null, how to calculate the angle $\theta$ from $\vec{V}$ to $\vec{W}$.

Let's call $M$ the rotation matrix: $M\vec{V} = \vec{W}$, and the components of $M$ as follow:

$$M = \begin{bmatrix} Ma & Mb \\ Mc & Md \end{bmatrix} = \begin{bmatrix} cos(\theta) & -sin(\theta) \\ sin(\theta) & cos(\theta) \end{bmatrix} \tag{3}$$

Then, $M\vec{V} = \vec{W}$ can be written has

$$\begin{cases} W_x = M_a V_x + M_b V_y \\ W_y = M_c V_x + M_d V_y \end{cases} \tag{4}$$

Equivalent to

$$\begin{cases} W_x = M_a V_x + M_b V_y \\ W_y = -M_b V_x + M_a V_y \end{cases} \tag{5}$$

where $M_a = cos(\theta)$ and $M_b = -sin(\theta)$.
If $Vx \neq 0.0$, we can write

$$\begin{cases} M_b = \frac{M_a V_y - W_y}{V_x} \\ M_a = \frac{W_x + W_y V_y / V_x}{V_x + V_y^2 / V_x} \end{cases} \tag{6}$$

Or, if $Vx = 0.0$, we can write

$$\begin{cases} Ma = \frac{W_y + M_b V_x}{V_y} \\ Mb = \frac{W_x - W_y V_x / V_y}{V_y + V_x^2 / V_y} \end{cases} \tag{7}$$

Then we have $\theta = \pm cos^{-1}(M_a)$ where the sign can be determined by verifying that the sign of $sin(\theta)$ matches the sign of $-M_b$: if $sin(cos^{-1}(M_a)) * M_b > 0.0$ then multiply $\theta = -cos^{-1}(M_a)$ else $\theta = cos^{-1}(M_a)$.

### 1.1.3 Rotation

Rotation if a vector is only defined in 2D and 3D. In 2D, for a right-handed rotation of angle $\theta$ the rotation matrix is equal to:

$$R = \begin{bmatrix} cos(\theta) & -sin(\theta) \\ sin(\theta) & cos(\theta) \end{bmatrix} \tag{8}$$

In 3D, for a right-handed rotation of angle $\theta$ around axis $\overrightarrow{u}$ the rotation is equal to (to shorten notation $\theta$ is not written in the matrix below):

$$R = \begin{bmatrix} cos + u_x^2(1-cos) & u_x u_y(1-cos) - u_z sin & u_x u_z(1-cos) + u_y sin \\ u_x u_y(1-cos) + u_z sin & cos + u_y^2(1-cos) & u_y u_z(1-cos) - u_x sin \\ u_x u_z(1-cos) - u_y sin & u_y u_z(1-cos) + u_x sin & cos + u_z^2(1-cos) \end{bmatrix} \tag{9}$$

## 1.2 Matrix

### 1.2.1 Inverse matrix

The inverse of a matrix is only implemented for square matrices less than 3x3. It is computed directly, based on the determinant and the adjoint matrix.

For a 2x2 matrix $M$:

$$M^{-1} = \frac{1}{det} \begin{bmatrix} M_3 & -M_2 \\ -M_1 & M_0 \end{bmatrix} \tag{10}$$

where

$$M = \begin{bmatrix} M_0 & M_2 \\ M_1 & M_3 \end{bmatrix} \tag{11}$$

and

$$det = M_0 M_3 - M_1 M_2 \tag{12}$$

For a 3x3 matrix $M$:

$$M^{-1} = \frac{1}{det} \begin{bmatrix} (M_4 M_8 - M_5 M_7) & -(M_3 M_8 - M_5 M_6) & (M_3 M_7 - M_4 M_6) \\ -(M_1 M_8 - M_2 M_7) & (M_0 M_8 - M_2 M_6) & -(M_0 M_7 - M_1 M_6) \\ (M_1 M_5 - M_2 M_4) & -(M_0 M_5 - M_2 M_3) & (M_0 M_4 - M_1 M_3) \end{bmatrix} \tag{13}$$

where

$$M = \begin{bmatrix} M_0 & M_3 & M_6 \\ M_1 & M_4 & M_7 \\ M_2 & M_5 & M_8 \end{bmatrix} \tag{14}$$

and

$$\begin{aligned} det = \; & M_0(M_4 M_8 - M_5 M_7) - \\ & M_3(M_1 M_8 - M_2 M_7) + \\ & M_6(M_1 M_5 - M_2 M_4) \end{aligned} \tag{15}$$

# 2 Interface

```
// ============ PBMATH.H ================

#ifndef PBMATH_H
#define PBMATH_H

// ================= Include =================

#include <stdlib.h>
#include <stdio.h>
#include <math.h>
#include <string.h>
#include <stdbool.h>
#include "pberr.h"

// ================= Define ==================

#define PBMATH_EPSILON 0.00001
#define PBMATH_TWOPI 6.283185307
#define PBMATH_TWOPI_DIV_360 0.01745329252
#define PBMATH_PI 3.141592654
#define PBMATH_HALFPI 1.570796327
#define PBMATH_QUARTERPI 0.7853981634
#define PBMATH_SQRTTWO 1.414213562
#define PBMATH_SQRTONEHALF 0.707106781
#if BUILDWITHGRAPHICLIB != 1
#define MAX(a,b) ((a)>(b)?(a):(b))
#define MIN(a,b) ((a)<(b)?(a):(b))
#endif
#define ISEQUALF(a,b) (fabs((a)-(b))<PBMATH_EPSILON)
#define SHORT(a) ((short)(round(a)))
#define INT(a) ((int)(round(a)))
#define rnd() (float)(rand())/(float)(RAND_MAX)

// ================= Polymorphism ==================

#define VecClone(Vec) _Generic(Vec, \
  VecFloat*: _VecFloatClone, \
  VecShort*: _VecShortClone, \
  default: PBErrInvalidPolymorphism)(Vec)

#define VecLoad(VecRef, Stream) _Generic(VecRef, \
  VecFloat**: _VecFloatLoad, \
  VecShort**: _VecShortLoad, \
  default: PBErrInvalidPolymorphism)(VecRef, Stream)

#define VecSave(Vec, Stream) _Generic(Vec, \
  VecFloat*: _VecFloatSave, \
  VecFloat2D*: _VecFloatSave, \
  VecFloat3D*: _VecFloatSave, \
  VecShort*: _VecShortSave, \
  VecShort2D*: _VecShortSave, \
  VecShort3D*: _VecShortSave, \
  VecShort4D*: _VecShortSave, \
  default: PBErrInvalidPolymorphism)( \
    _Generic(Vec,  \
      VecFloat2D*: (VecFloat*)(Vec), \
      VecFloat3D*: (VecFloat*)(Vec), \
      VecShort2D*: (VecShort*)(Vec), \
      VecShort3D*: (VecShort*)(Vec), \
```

```
      VecShort4D*: (VecShort*)(Vec), \
      default: Vec),  \
    Stream)

#define VecFree(VecRef) _Generic(VecRef, \
  VecFloat**: _VecFloatFree, \
  VecShort**: _VecShortFree, \
  default: PBErrInvalidPolymorphism)(VecRef)

#define VecPrint(Vec, Stream) _Generic(Vec, \
  VecFloat*: _VecFloatPrintDef, \
  VecFloat2D*: _VecFloatPrintDef, \
  VecFloat3D*: _VecFloatPrintDef, \
  VecShort*: _VecShortPrint, \
  VecShort2D*: _VecShortPrint, \
  VecShort3D*: _VecShortPrint, \
  VecShort4D*: _VecShortPrint, \
  default: PBErrInvalidPolymorphism)( \
    _Generic(Vec,  \
      VecFloat2D*: (VecFloat*)(Vec), \
      VecFloat3D*: (VecFloat*)(Vec), \
      VecShort2D*: (VecShort*)(Vec), \
      VecShort3D*: (VecShort*)(Vec), \
      VecShort4D*: (VecShort*)(Vec), \
      default: Vec),  \
    Stream)

#define VecGet(Vec, Index) _Generic(Vec, \
  VecFloat*: _VecFloatGet, \
  VecFloat2D*: _VecFloatGet2D, \
  VecFloat3D*: _VecFloatGet3D, \
  VecShort*: _VecShortGet, \
  VecShort2D*: _VecShortGet2D, \
  VecShort3D*: _VecShortGet3D, \
  VecShort4D*: _VecShortGet4D, \
  default: PBErrInvalidPolymorphism)(Vec, Index)

#define VecSet(Vec, Index, Val) _Generic(Vec, \
  VecFloat*: _VecFloatSet, \
  VecFloat2D*: _VecFloatSet2D, \
  VecFloat3D*: _VecFloatSet3D, \
  VecShort*: _VecShortSet, \
  VecShort2D*: _VecShortSet2D, \
  VecShort3D*: _VecShortSet3D, \
  VecShort4D*: _VecShortSet4D, \
  default: PBErrInvalidPolymorphism)(Vec, Index, Val)

#define VecSetNull(Vec) _Generic(Vec, \
  VecFloat*: _VecFloatSetNull, \
  VecFloat2D*: _VecFloatSetNull, \
  VecFloat3D*: _VecFloatSetNull, \
  VecShort*: _VecShortSetNull, \
  VecShort2D*: _VecShortSetNull, \
  VecShort3D*: _VecShortSetNull, \
  VecShort4D*: _VecShortSetNull, \
  default: PBErrInvalidPolymorphism)( \
    _Generic(Vec,  \
      VecFloat2D*: (VecFloat*)(Vec), \
      VecFloat3D*: (VecFloat*)(Vec), \
      VecShort2D*: (VecShort*)(Vec), \
      VecShort3D*: (VecShort*)(Vec), \
      VecShort4D*: (VecShort*)(Vec), \
```

```
      default: Vec))

#define VecCopy(VecDest, VecSrc) _Generic(VecDest, \
  VecFloat*: _Generic(VecSrc, \
    VecFloat*: _VecFloatCopy, \
    VecFloat2D*: _VecFloatCopy, \
    VecFloat3D*: _VecFloatCopy, \
    default: PBErrInvalidPolymorphism), \
  VecFloat2D*: _Generic(VecSrc, \
    VecFloat*: _VecFloatCopy, \
    VecFloat2D*: _VecFloatCopy, \
    default: PBErrInvalidPolymorphism), \
  VecFloat3D*: _Generic(VecSrc, \
    VecFloat*: _VecFloatCopy, \
    VecFloat3D*: _VecFloatCopy, \
    default: PBErrInvalidPolymorphism), \
  VecShort*: _Generic(VecSrc, \
    VecShort*: _VecShortCopy, \
    VecShort2D*: _VecShortCopy, \
    VecShort3D*: _VecShortCopy, \
    VecShort4D*: _VecShortCopy, \
    default: PBErrInvalidPolymorphism), \
  VecShort2D*: _Generic(VecSrc, \
    VecShort*: _VecShortCopy, \
    VecShort2D*: _VecShortCopy, \
    default: PBErrInvalidPolymorphism), \
  VecShort3D*: _Generic(VecSrc, \
    VecShort*: _VecShortCopy, \
    VecShort3D*: _VecShortCopy, \
    default: PBErrInvalidPolymorphism), \
  VecShort4D*: _Generic(VecSrc, \
    VecShort*: _VecShortCopy, \
    VecShort4D*: _VecShortCopy, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)( \
    _Generic(VecDest,  \
      VecFloat2D*: (VecFloat*)(VecDest), \
      VecFloat3D*: (VecFloat*)(VecDest), \
      VecShort2D*: (VecShort*)(VecDest), \
      VecShort3D*: (VecShort*)(VecDest), \
      VecShort4D*: (VecShort*)(VecDest), \
      default: VecDest),  \
    _Generic(VecSrc,  \
      VecFloat2D*: (VecFloat*)(VecSrc), \
      VecFloat3D*: (VecFloat*)(VecSrc), \
      VecShort2D*: (VecShort*)(VecSrc), \
      VecShort3D*: (VecShort*)(VecSrc), \
      VecShort4D*: (VecShort*)(VecSrc), \
      default: VecSrc))

#define VecGetDim(Vec) _Generic(Vec, \
  VecFloat*: _VecFloatGetDim, \
  VecFloat2D*: _VecFloatGetDim, \
  VecFloat3D*: _VecFloatGetDim, \
  VecShort*: _VecShortGetDim, \
  VecShort2D*: _VecShortGetDim, \
  VecShort3D*: _VecShortGetDim, \
  VecShort4D*: _VecShortGetDim, \
  default: PBErrInvalidPolymorphism)( \
    _Generic(Vec, \
      VecFloat*: Vec, \
      VecFloat2D*: (VecFloat*)(Vec), \
```

```
      VecFloat3D*: (VecFloat*)(Vec), \
      VecShort*: Vec, \
      VecShort2D*: (VecShort*)(Vec), \
      VecShort3D*: (VecShort*)(Vec), \
      VecShort4D*: (VecShort*)(Vec), \
      default: Vec))

#define VecNorm(Vec) _Generic(Vec, \
  VecFloat*: _VecFloatNorm, \
  VecFloat2D*: _VecFloatNorm2D, \
  VecFloat3D*: _VecFloatNorm3D, \
  default: PBErrInvalidPolymorphism)(Vec)

#define VecNormalise(Vec) _Generic(Vec, \
  VecFloat*: _VecFloatNormalise, \
  VecFloat2D*: _VecFloatNormalise2D, \
  VecFloat3D*: _VecFloatNormalise3D, \
  default: PBErrInvalidPolymorphism)(Vec)

#define VecDist(VecA, VecB) _Generic(VecA, \
  VecFloat*: _Generic(VecB, \
    VecFloat*: _VecFloatDist, \
    default: PBErrInvalidPolymorphism), \
  VecFloat2D*: _Generic(VecB, \
    VecFloat2D*: _VecFloatDist2D, \
    default: PBErrInvalidPolymorphism), \
  VecFloat3D*: _Generic(VecB, \
    VecFloat3D*: _VecFloatDist3D, \
    default: PBErrInvalidPolymorphism), \
  VecShort*: _Generic(VecB, \
    VecShort*: _VecShortHamiltonDist,\
    default: PBErrInvalidPolymorphism), \
  VecShort2D*: _Generic(VecB, \
    VecShort2D*: _VecShortHamiltonDist2D,\
    default: PBErrInvalidPolymorphism), \
  VecShort3D*: _Generic(VecB, \
    VecShort3D*: _VecShortHamiltonDist3D,\
    default: PBErrInvalidPolymorphism), \
  VecShort4D*: _Generic(VecB, \
    VecShort4D*: _VecShortHamiltonDist4D,\
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(VecA, VecB)

#define VecHamiltonDist(VecA, VecB) _Generic(VecA, \
  VecFloat*: _Generic(VecB, \
    VecFloat*: _VecFloatHamiltonDist, \
    default: PBErrInvalidPolymorphism), \
  VecFloat2D*: _Generic(VecB, \
    VecFloat2D*: _VecFloatHamiltonDist2D, \
    default: PBErrInvalidPolymorphism), \
  VecFloat3D*: _Generic(VecB, \
    VecFloat3D*: _VecFloatHamiltonDist3D, \
    default: PBErrInvalidPolymorphism), \
  VecShort*: _Generic(VecB, \
    VecShort*: _VecShortHamiltonDist,\
    default: PBErrInvalidPolymorphism), \
  VecShort2D*: _Generic(VecB, \
    VecShort2D*: _VecShortHamiltonDist2D,\
    default: PBErrInvalidPolymorphism), \
  VecShort3D*: _Generic(VecB, \
    VecShort3D*: _VecShortHamiltonDist3D,\
    default: PBErrInvalidPolymorphism), \
```

```
  VecShort4D*: _Generic(VecB, \
    VecShort4D*: _VecShortHamiltonDist4D,\
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(VecA, VecB)

#define VecPixelDist(VecA, VecB) _Generic(VecA, \
  VecFloat*: _Generic(VecB, \
    VecFloat*: _VecFloatPixelDist, \
    default: PBErrInvalidPolymorphism), \
  VecFloat2D*: _Generic(VecB, \
    VecFloat2D*: _VecFloatPixelDist2D, \
    default: PBErrInvalidPolymorphism), \
  VecFloat3D*: _Generic(VecB, \
    VecFloat3D*: _VecFloatPixelDist3D, \
    default: PBErrInvalidPolymorphism), \
  VecShort*: _Generic(VecB, \
    VecShort*: _VecShortHamiltonDist,\
    default: PBErrInvalidPolymorphism), \
  VecShort2D*: _Generic(VecB, \
    VecShort2D*: _VecShortHamiltonDist2D,\
    default: PBErrInvalidPolymorphism), \
  VecShort3D*: _Generic(VecB, \
    VecShort3D*: _VecShortHamiltonDist3D,\
    default: PBErrInvalidPolymorphism), \
  VecShort4D*: _Generic(VecB, \
    VecShort4D*: _VecShortHamiltonDist4D,\
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(VecA, VecB)

#define VecIsEqual(VecA, VecB) _Generic(VecA, \
  VecFloat*: _Generic(VecB, \
    VecFloat*: _VecFloatIsEqual, \
    VecFloat2D*: _VecFloatIsEqual, \
    VecFloat3D*: _VecFloatIsEqual, \
    default: PBErrInvalidPolymorphism), \
  VecFloat2D*: _Generic(VecB, \
    VecFloat*: _VecFloatIsEqual, \
    VecFloat2D*: _VecFloatIsEqual, \
    default: PBErrInvalidPolymorphism), \
  VecFloat3D*: _Generic(VecB, \
    VecFloat*: _VecFloatIsEqual, \
    VecFloat3D*: _VecFloatIsEqual, \
    default: PBErrInvalidPolymorphism), \
  VecShort*: _Generic(VecB, \
    VecShort*: _VecShortIsEqual,\
    VecShort2D*: _VecShortIsEqual,\
    VecShort3D*: _VecShortIsEqual,\
    VecShort4D*: _VecShortIsEqual,\
    default: PBErrInvalidPolymorphism), \
  VecShort2D*: _Generic(VecB, \
    VecShort*: _VecShortIsEqual,\
    VecShort2D*: _VecShortIsEqual,\
    default: PBErrInvalidPolymorphism), \
  VecShort3D*: _Generic(VecB, \
    VecShort*: _VecShortIsEqual,\
    VecShort3D*: _VecShortIsEqual,\
    default: PBErrInvalidPolymorphism), \
  VecShort4D*: _Generic(VecB, \
    VecShort*: _VecShortIsEqual,\
    VecShort4D*: _VecShortIsEqual,\
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)( \
```

```
    _Generic(VecA,  \
      VecFloat2D*: (VecFloat*)(VecA), \
      VecFloat3D*: (VecFloat*)(VecA), \
      VecShort2D*: (VecShort*)(VecA), \
      VecShort3D*: (VecShort*)(VecA), \
      VecShort4D*: (VecShort*)(VecA), \
      default: VecA),  \
    _Generic(VecB,  \
      VecFloat2D*: (VecFloat*)(VecB), \
      VecFloat3D*: (VecFloat*)(VecB), \
      VecShort2D*: (VecShort*)(VecB), \
      VecShort3D*: (VecShort*)(VecB), \
      VecShort4D*: (VecShort*)(VecB), \
      default: VecB))

#define VecOp(VecA, CoeffA, VecB, CoeffB) _Generic(VecA, \
  VecFloat*: _Generic(VecB, \
    VecFloat*: _VecFloatOp, \
    default: PBErrInvalidPolymorphism), \
  VecFloat2D*: _Generic(VecB, \
    VecFloat2D*: _VecFloatOp2D, \
    default: PBErrInvalidPolymorphism), \
  VecFloat3D*: _Generic(VecB, \
    VecFloat3D*: _VecFloatOp3D, \
    default: PBErrInvalidPolymorphism), \
  VecShort*: _Generic(VecB, \
    VecShort*: _VecShortOp, \
    default: PBErrInvalidPolymorphism), \
  VecShort2D*: _Generic(VecB, \
    VecShort2D*: _VecShortOp2D, \
    default: PBErrInvalidPolymorphism), \
  VecShort3D*: _Generic(VecB, \
    VecShort3D*: _VecShortOp3D, \
    default: PBErrInvalidPolymorphism), \
  VecShort4D*: _Generic(VecB, \
    VecShort4D*: _VecShortOp4D, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(VecA, CoeffA, VecB, CoeffB)

#define VecGetOp(VecA, CoeffA, VecB, CoeffB) _Generic(VecA, \
  VecFloat*: _Generic(VecB, \
    VecFloat*: _VecFloatGetOp, \
    default: PBErrInvalidPolymorphism), \
  VecFloat2D*: _Generic(VecB, \
    VecFloat2D*: _VecFloatGetOp2D, \
    default: PBErrInvalidPolymorphism), \
  VecFloat3D*: _Generic(VecB, \
    VecFloat3D*: _VecFloatGetOp3D, \
    default: PBErrInvalidPolymorphism), \
  VecShort*: _Generic(VecB, \
    VecShort*: _VecShortGetOp, \
    default: PBErrInvalidPolymorphism), \
  VecShort2D*: _Generic(VecB, \
    VecShort2D*: _VecShortGetOp2D, \
    default: PBErrInvalidPolymorphism), \
  VecShort3D*: _Generic(VecB, \
    VecShort3D*: _VecShortGetOp3D, \
    default: PBErrInvalidPolymorphism), \
  VecShort4D*: _Generic(VecB, \
    VecShort4D*: _VecShortGetOp4D, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(VecA, CoeffA, VecB, CoeffB)
```

```
#define VecScale(Vec, Scale) _Generic(Vec, \
  VecFloat*: _VecFloatScale, \
  VecFloat2D*: _VecFloatScale2D, \
  VecFloat3D*: _VecFloatScale3D, \
  default: PBErrInvalidPolymorphism)(Vec, Scale)

#define VecGetScale(Vec, Scale) _Generic(Vec, \
  VecFloat*: _VecFloatGetScale, \
  VecFloat2D*: _VecFloatGetScale2D, \
  VecFloat3D*: _VecFloatGetScale3D, \
  default: PBErrInvalidPolymorphism)(Vec, Scale)

#define VecRot(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatRot2D, \
  VecFloat2D*: _VecFloatRot2D, \
  default: PBErrInvalidPolymorphism)((VecFloat2D*)(Vec), Theta)

#define VecGetRot(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatGetRot2D, \
  VecFloat2D*: _VecFloatGetRot2D, \
  default: PBErrInvalidPolymorphism)((VecFloat2D*)(Vec), Theta)

#define VecRotAxis(Vec, Axis, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatRotAxis, \
  VecFloat3D*: _VecFloatRotAxis, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), \
    (VecFloat3D*)(Axis), Theta)

#define VecGetRotAxis(Vec, Axis, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatGetRotAxis, \
  VecFloat3D*: _VecFloatGetRotAxis, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), \
    (VecFloat3D*)(Axis), Theta)

#define VecRotX(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatRotX, \
  VecFloat3D*: _VecFloatRotX, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), Theta)

#define VecGetRotX(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatGetRotX, \
  VecFloat3D*: _VecFloatGetRotX, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), Theta)

#define VecRotY(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatRotY, \
  VecFloat3D*: _VecFloatRotY, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), Theta)

#define VecGetRotY(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatGetRotY, \
  VecFloat3D*: _VecFloatGetRotY, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), Theta)

#define VecRotZ(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatRotZ, \
  VecFloat3D*: _VecFloatRotZ, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), Theta)

#define VecGetRotZ(Vec, Theta) _Generic(Vec, \
  VecFloat*: _VecFloatGetRotZ, \
```

```
  VecFloat3D*: _VecFloatGetRotZ, \
  default: PBErrInvalidPolymorphism)((VecFloat3D*)(Vec), Theta)

#define VecDotProd(VecA, VecB) _Generic(VecA, \
  VecShort*: _VecShortDotProd,\
  VecShort2D*: _VecShortDotProd2D,\
  VecShort3D*: _VecShortDotProd3D,\
  VecShort4D*: _VecShortDotProd4D,\
  VecFloat*: _VecFloatDotProd, \
  VecFloat2D*: _VecFloatDotProd2D, \
  VecFloat3D*: _VecFloatDotProd3D, \
  default: PBErrInvalidPolymorphism) (VecA, VecB) \

#define VecAngleTo(VecFrom, VecTo) _Generic(VecFrom, \
  VecFloat*: _VecFloatAngleTo2D, \
  VecFloat2D*: _VecFloatAngleTo2D, \
  default: PBErrInvalidPolymorphism)((VecFloat2D*)(VecFrom), \
    (VecFloat2D*)(VecTo))

#define VecStep(Vec, VecBound) _Generic(Vec, \
  VecShort*: _VecShortStep, \
  VecShort2D*: _VecShortStep, \
  VecShort3D*: _VecShortStep, \
  VecShort4D*: _VecShortStep, \
  default: PBErrInvalidPolymorphism)((VecShort*)(Vec), \
    (VecShort*)(VecBound))

#define VecPStep(Vec, VecBound) _Generic(Vec, \
  VecShort*: _VecShortPStep, \
  VecShort2D*: _VecShortPStep, \
  VecShort3D*: _VecShortPStep, \
  VecShort4D*: _VecShortPStep, \
  default: PBErrInvalidPolymorphism)((VecShort*)(Vec), \
    (VecShort*)(VecBound))

#define VecShiftStep(Vec, VecFrom, VecTo) _Generic(Vec, \
  VecShort*: _VecShortShiftStep, \
  VecShort2D*: _VecShortShiftStep, \
  VecShort3D*: _VecShortShiftStep, \
  VecShort4D*: _VecShortShiftStep, \
  default: PBErrInvalidPolymorphism)((VecShort*)(Vec), \
    (VecShort*)(VecFrom), (VecShort*)(VecTo))

#define VecGetMaxVal(Vec) _Generic(Vec, \
  VecFloat*: _VecFloatGetMaxVal, \
  VecFloat2D*: _VecFloatGetMaxVal, \
  VecFloat3D*: _VecFloatGetMaxVal, \
  VecShort*: _VecShortGetMaxVal, \
  VecShort2D*: _VecShortGetMaxVal, \
  VecShort3D*: _VecShortGetMaxVal, \
  VecShort4D*: _VecShortGetMaxVal, \
  default: PBErrInvalidPolymorphism) (_Generic(Vec, \
    VecFloat2D*: (VecFloat*)(Vec), \
    VecFloat3D*: (VecFloat*)(Vec), \
    VecShort2D*: (VecShort*)(Vec), \
    VecShort3D*: (VecShort*)(Vec), \
    VecShort4D*: (VecShort*)(Vec), \
    default: Vec))

#define VecGetMinVal(Vec) _Generic(Vec, \
  VecFloat*: _VecFloatGetMinVal, \
  VecFloat2D*: _VecFloatGetMinVal, \
```

```
  VecFloat3D*: _VecFloatGetMinVal, \
  VecShort*: _VecShortGetMinVal, \
  VecShort2D*: _VecShortGetMinVal, \
  VecShort3D*: _VecShortGetMinVal, \
  VecShort4D*: _VecShortGetMinVal, \
  default: PBErrInvalidPolymorphism) (_Generic(Vec, \
    VecFloat2D*: (VecFloat*)(Vec), \
    VecFloat3D*: (VecFloat*)(Vec), \
    VecShort2D*: (VecShort*)(Vec), \
    VecShort3D*: (VecShort*)(Vec), \
    VecShort4D*: (VecShort*)(Vec), \
    default: Vec))

#define VecStepDelta(Vec, VecBound, Delta) _Generic(Vec, \
  VecFloat*: _VecFloatStepDelta, \
  VecFloat2D*: _VecFloatStepDelta, \
  VecFloat3D*: _VecFloatStepDelta, \
  default: PBErrInvalidPolymorphism)((VecFloat*)(Vec), \
    (VecFloat*)(VecBound), (VecFloat*)(Delta))

#define VecShiftStepDelta(Vec, VecFrom, VecTo, Delta) _Generic(Vec, \
  VecFloat*: _VecFloatShiftStepDelta, \
  VecFloat2D*: _VecFloatShiftStepDelta, \
  VecFloat3D*: _VecFloatShiftStepDelta, \
  default: PBErrInvalidPolymorphism)((VecFloat*)(Vec), \
    (VecFloat*)(VecFrom), (VecFloat*)(VecTo), (VecFloat*)(Delta))

#define MatClone(Mat) _Generic(Mat, \
  MatFloat*: _MatFloatClone, \
  default: PBErrInvalidPolymorphism)(Mat)

#define MatLoad(MatRef, Stream) _Generic(MatRef, \
  MatFloat**: _MatFloatLoad, \
  default: PBErrInvalidPolymorphism)(MatRef, Stream)

#define MatSave(Mat, Stream) _Generic(Mat, \
  MatFloat*: _MatFloatSave, \
  default: PBErrInvalidPolymorphism)(Mat, Stream)

#define MatFree(MatRef) _Generic(MatRef, \
  MatFloat**: _MatFloatFree, \
  default: PBErrInvalidPolymorphism)(MatRef)

#define MatPrintln(Mat, Stream) _Generic(Mat, \
  MatFloat*: _MatFloatPrintlnDef, \
  default: PBErrInvalidPolymorphism)(Mat, Stream)

#define MatGet(Mat, VecIndex) _Generic(Mat, \
  MatFloat*: _MatFloatGet, \
  default: PBErrInvalidPolymorphism)(Mat, VecIndex)

#define MatSet(Mat, VecIndex, Val) _Generic(Mat, \
  MatFloat*: _MatFloatSet, \
  default: PBErrInvalidPolymorphism)(Mat, VecIndex, Val)

#define MatCopy(MatDest, MatSrc) _Generic(MatDest, \
  MatFloat*: _Generic (MatSrc, \
    MatFloat*: _MatFloatCopy, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(MatDest, MatSrc)

#define MatDim(Mat) _Generic(Mat, \
```

```
  MatFloat*: _MatFloatDim, \
  default: PBErrInvalidPolymorphism)(Mat)

#define MatGetDim(Mat) _Generic(Mat, \
  MatFloat*: _MatFloatGetDim, \
  default: PBErrInvalidPolymorphism)(Mat)

#define MatInv(Mat) _Generic(Mat, \
  MatFloat*: _MatFloatInv, \
  default: PBErrInvalidPolymorphism)(Mat)

#define MatGetProdMat(MatA, MatB) _Generic(MatA, \
  MatFloat*: _Generic(MatB, \
    MatFloat*: _MatFloatGetProdMatFloat, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(MatA, MatB)

#define MatGetProdVec(Mat, Vec) _Generic(Mat, \
  MatFloat*: _Generic(Vec, \
    VecFloat*: _MatFloatGetProdVecFloat, \
    VecFloat2D*: _MatFloatGetProdVecFloat, \
    VecFloat3D*: _MatFloatGetProdVecFloat, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(Mat, (VecFloat*)(Vec))

#define MatAdd(MatA, MatB) _Generic(MatA, \
  MatFloat*: _Generic(MatB, \
    MatFloat*: _MatFloatAdd, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(MatA, MatB)

#define MatGetAdd(MatA, MatB) _Generic(MatA, \
  MatFloat*: _Generic(MatB, \
    MatFloat*: _MatFloatGetAdd, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(MatA, MatB)

#define MatSetIdentity(Mat) _Generic(Mat, \
  MatFloat*: _MatFloatSetIdentity, \
  default: PBErrInvalidPolymorphism)(Mat)

#define MatIsEqual(MatA, MatB) _Generic(MatA, \
  MatFloat*: _Generic(MatB, \
    MatFloat*: _MatFloatIsEqual, \
    default: PBErrInvalidPolymorphism), \
  default: PBErrInvalidPolymorphism)(MatA, MatB)

#define SysLinEqCreate(Mat, Vec) _Generic(Vec, \
  VecFloat*: _SLECreate, \
  VecFloat2D*: _SLECreate, \
  VecFloat3D*: _SLECreate, \
  default: PBErrInvalidPolymorphism)(Mat, (VecFloat*)(Vec))

#define SysLinEqSetV(Sys, Vec) _Generic(Vec, \
  VecFloat*: _SLESetV, \
  VecFloat2D*: _SLESetV, \
  VecFloat3D*: _SLESetV, \
  default: PBErrInvalidPolymorphism)(Sys, (VecFloat*)(Vec))

// -------------- VecShort

// ================= Data structure ===================
```

```
// Vector of short values
typedef struct VecShort {
  // Dimension
  int _dim;
  // Values
  short _val[0];
} VecShort;

typedef struct VecShort2D {
  // Dimension
  int _dim;
  // Values
  short _val[2];
} VecShort2D;

typedef struct VecShort3D {
  // Dimension
  int _dim;
  // Values
  short _val[3];
} VecShort3D;

typedef struct VecShort4D {
  // Dimension
  int _dim;
  // Values
  short _val[4];
} VecShort4D;

// ================ Functions declaration ====================

// Create a new VecShort of dimension 'dim'
// Values are initalized to 0.0
VecShort* VecShortCreate(int dim);

// Static constructors for VecShort
#if BUILDMODE != 0
inline
#endif
VecShort2D VecShortCreateStatic2D();
#if BUILDMODE != 0
inline
#endif
VecShort3D VecShortCreateStatic3D();
#if BUILDMODE != 0
inline
#endif
VecShort4D VecShortCreateStatic4D();

// Clone the VecShort
// Return NULL if we couldn't clone the VecShort
VecShort* _VecShortClone(VecShort* that);

// Load the VecShort from the stream
// If the VecShort is already allocated, it is freed before loading
// Return true in case of success, else false
bool _VecShortLoad(VecShort** that, FILE* stream);

// Save the VecShort to the stream
// Return true in case of success, else false
bool _VecShortSave(VecShort* that, FILE* stream);
```

```
// Free the memory used by a VecShort
// Do nothing if arguments are invalid
void _VecShortFree(VecShort** that);

// Print the VecShort on 'stream'
void _VecShortPrint(VecShort* that, FILE* stream);

// Return the i-th value of the VecShort
#if BUILDMODE != 0
inline
#endif
short _VecShortGet(VecShort* that, int i);
#if BUILDMODE != 0
inline
#endif
short _VecShortGet2D(VecShort2D* that, int i);
#if BUILDMODE != 0
inline
#endif
short _VecShortGet3D(VecShort3D* that, int i);
#if BUILDMODE != 0
inline
#endif
short _VecShortGet4D(VecShort4D* that, int i);

// Set the i-th value of the VecShort to v
#if BUILDMODE != 0
inline
#endif
void _VecShortSet(VecShort* that, int i, short v);
#if BUILDMODE != 0
inline
#endif
void _VecShortSet2D(VecShort2D* that, int i, short v);
#if BUILDMODE != 0
inline
#endif
void _VecShortSet3D(VecShort3D* that, int i, short v);
#if BUILDMODE != 0
inline
#endif
void _VecShortSet4D(VecShort4D* that, int i, short v);

// Return the dimension of the VecShort
// Return 0 if arguments are invalid
#if BUILDMODE != 0
inline
#endif
int _VecShortGetDim(VecShort* that);

// Return the Hamiltonian distance between the VecShort 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
short _VecShortHamiltonDist(VecShort* that, VecShort* tho);
#if BUILDMODE != 0
inline
#endif
short _VecShortHamiltonDist2D(VecShort2D* that, VecShort2D* tho);
#if BUILDMODE != 0
inline
```

```
#endif
short _VecShortHamiltonDist3D(VecShort3D* that, VecShort3D* tho);
#if BUILDMODE != 0
inline
#endif
short _VecShortHamiltonDist4D(VecShort4D* that, VecShort4D* tho);

// Return true if the VecShort 'that' is equal to 'tho', else false
#if BUILDMODE != 0
inline
#endif
bool _VecShortIsEqual(VecShort* that, VecShort* tho);

// Copy the values of 'w' in 'that' (must have same dimensions)
#if BUILDMODE != 0
inline
#endif
void _VecShortCopy(VecShort* that, VecShort* w);

// Return the dot product of 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd(VecShort* that, VecShort* tho);
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd2D(VecShort2D* that, VecShort2D* tho);
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd3D(VecShort3D* that, VecShort3D* tho);
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd4D(VecShort4D* that, VecShort4D* tho);

// Set all values of the vector 'that' to 0
#if BUILDMODE != 0
inline
#endif
void _VecShortSetNull(VecShort* that);

// Step the values of the vector incrementally by 1 from 0
// in the following order (for example) :
// (0,0,0)->(0,0,1)->(0,0,2)->(0,1,0)->(0,1,1)->...
// The upper limit for each value is given by 'bound' (val[i] < dim[i])
// Return false if all values of 'that' have reached their upper limit
// (in which case 'that''s values are all set back to 0)
// Return true else
bool _VecShortStep(VecShort* that, VecShort* bound);

// Step the values of the vector incrementally by 1 from 0
// in the following order (for example) :
// (0,0,0)->(1,0,0)->(2,0,0)->(0,1,0)->(1,1,0)->...
// The upper limit for each value is given by 'bound' (val[i] < dim[i])
// Return false if all values of 'that' have reached their upper limit
// (in which case 'that''s values are all set back to 0)
// Return true else
bool _VecShortPStep(VecShort* that, VecShort* bound);

// Step the values of the vector incrementally by 1
```

```
// in the following order (for example) :
// (0,0,0)->(0,0,1)->(0,0,2)->(0,1,0)->(0,1,1)->...
// The lower limit for each value is given by 'from' (val[i] >= from[i])
// The upper limit for each value is given by 'to' (val[i] < to[i])
// 'that' must be initialised to 'from' before the first call of this
// function
// Return false if all values of 'that' have reached their upper limit
// (in which case 'that''s values are all set back to from)
// Return true else
bool _VecShortShiftStep(VecShort* that, VecShort* from, VecShort* to);

// Calculate (that * a + tho * b) and store the result in 'that'
// 'tho' can be null, in which case it is consider to be the null vector
// If 'tho' is not null it must be of same dimension as 'that'
#if BUILDMODE != 0
inline
#endif
void _VecShortOp(VecShort* that, short a, VecShort* tho, short b);
#if BUILDMODE != 0
inline
#endif
void _VecShortOp2D(VecShort2D* that, short a, VecShort2D* tho, short b);
#if BUILDMODE != 0
inline
#endif
void _VecShortOp3D(VecShort3D* that, short a, VecShort3D* tho, short b);
#if BUILDMODE != 0
inline
#endif
void _VecShortOp4D(VecShort4D* that, short a, VecShort4D* tho, short b);

// Return a VecShort equal to (that * a + tho * b)
// Return NULL if arguments are invalid
// 'tho' can be null, in which case it is consider to be the null vector
// If 'tho' is not null it must be of same dimension as 'that'
#if BUILDMODE != 0
inline
#endif
VecShort* _VecShortGetOp(VecShort* that, short a,
  VecShort* tho, short b);
#if BUILDMODE != 0
inline
#endif
VecShort2D _VecShortGetOp2D(VecShort2D* that, short a,
  VecShort2D* tho, short b);
#if BUILDMODE != 0
inline
#endif
VecShort3D _VecShortGetOp3D(VecShort3D* that, short a,
  VecShort3D* tho, short b);
#if BUILDMODE != 0
inline
#endif
VecShort4D _VecShortGetOp4D(VecShort4D* that, short a,
  VecShort4D* tho, short b);

// Get the max value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
short _VecShortGetMaxVal(VecShort* that);
```

```
// Get the min value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
short _VecShortGetMinVal(VecShort* that);

// -------------- VecFloat

// ================= Data structure ===================

// Vector of float values
typedef struct VecFloat {
  // Dimension
  int _dim;
  // Values
  float _val[0];
} VecFloat;

typedef struct VecFloat2D {
  // Dimension
  int _dim;
  // Values
  float _val[2];
} VecFloat2D;

typedef struct VecFloat3D {
  // Dimension
  int _dim;
  // Values
  float _val[3];
} VecFloat3D;

// ================ Functions declaration ====================

// Create a new VecFloat of dimension 'dim'
// Values are initalized to 0.0
VecFloat* VecFloatCreate(int dim);

// Static constructors for VecFloat
#if BUILDMODE != 0
inline
#endif
VecFloat2D VecFloatCreateStatic2D();
#if BUILDMODE != 0
inline
#endif
VecFloat3D VecFloatCreateStatic3D();

// Clone the VecFloat
VecFloat* _VecFloatClone(VecFloat* that);

// Load the VecFloat from the stream
// If the VecFloat is already allocated, it is freed before loading
// Return true in case of success, else false
bool _VecFloatLoad(VecFloat** that, FILE* stream);

// Save the VecFloat to the stream
// Return true in case of success, else false
bool _VecFloatSave(VecFloat* that, FILE* stream);

// Free the memory used by a VecFloat
// Do nothing if arguments are invalid
```

```
void _VecFloatFree(VecFloat** that);

// Print the VecFloat on 'stream' with 'prec' digit precision
// Do nothing if arguments are invalid
void VecFloatPrint(VecFloat* that, FILE* stream, unsigned int prec);
inline void _VecFloatPrintDef(VecFloat* that, FILE* stream) {
  VecFloatPrint(that, stream, 3);
}

// Return the 'i'-th value of the VecFloat
#if BUILDMODE != 0
inline
#endif
float _VecFloatGet(VecFloat* that, int i);
#if BUILDMODE != 0
inline
#endif
float _VecFloatGet2D(VecFloat2D* that, int i);
#if BUILDMODE != 0
inline
#endif
float _VecFloatGet3D(VecFloat3D* that, int i);

// Set the 'i'-th value of the VecFloat to 'v'
#if BUILDMODE != 0
inline
#endif
void _VecFloatSet(VecFloat* that, int i, float v);
#if BUILDMODE != 0
inline
#endif
void _VecFloatSet2D(VecFloat2D* that, int i, float v);
#if BUILDMODE != 0
inline
#endif
void _VecFloatSet3D(VecFloat3D* that, int i, float v);

// Set all values of the vector 'that' to 0
#if BUILDMODE != 0
inline
#endif
void _VecFloatSetNull(VecFloat* that);
#if BUILDMODE != 0
inline
#endif
void _VecFloatSetNull2D(VecFloat2D* that);
#if BUILDMODE != 0
inline
#endif
void _VecFloatSetNull3D(VecFloat3D* that);

// Return the dimension of the VecFloat
// Return 0 if arguments are invalid
#if BUILDMODE != 0
inline
#endif
int _VecFloatGetDim(VecFloat* that);

// Copy the values of 'w' in 'that' (must have same dimensions)
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
```

```
#endif
void _VecFloatCopy(VecFloat* that, VecFloat* w);

// Return the norm of the VecFloat
// Return 0.0 if arguments are invalid
#if BUILDMODE != 0
inline
#endif
float _VecFloatNorm(VecFloat* that);
#if BUILDMODE != 0
inline
#endif
float _VecFloatNorm2D(VecFloat2D* that);
#if BUILDMODE != 0
inline
#endif
float _VecFloatNorm3D(VecFloat3D* that);

// Normalise the VecFloat
#if BUILDMODE != 0
inline
#endif
void _VecFloatNormalise(VecFloat* that);
#if BUILDMODE != 0
inline
#endif
void _VecFloatNormalise2D(VecFloat2D* that);
#if BUILDMODE != 0
inline
#endif
void _VecFloatNormalise3D(VecFloat3D* that);

// Return the distance between the VecFloat 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
float _VecFloatDist(VecFloat* that, VecFloat* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatDist2D(VecFloat2D* that, VecFloat2D* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatDist3D(VecFloat3D* that, VecFloat3D* tho);

// Return the Hamiltonian distance between the VecFloat 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
float _VecFloatHamiltonDist(VecFloat* that, VecFloat* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatHamiltonDist2D(VecFloat2D* that, VecFloat2D* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatHamiltonDist3D(VecFloat3D* that, VecFloat3D* tho);

// Return the Pixel distance between the VecFloat 'that' and 'tho'
#if BUILDMODE != 0
```

```
inline
#endif
float _VecFloatPixelDist(VecFloat* that, VecFloat* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatPixelDist2D(VecFloat2D* that, VecFloat2D* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatPixelDist3D(VecFloat3D* that, VecFloat3D* tho);

// Return true if the VecFloat 'that' is equal to 'tho', else false
#if BUILDMODE != 0
inline
#endif
bool _VecFloatIsEqual(VecFloat* that, VecFloat* tho);

// Calculate (that * a) and store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatScale(VecFloat* that, float a);
#if BUILDMODE != 0
inline
#endif
void _VecFloatScale2D(VecFloat2D* that, float a);
#if BUILDMODE != 0
inline
#endif
void _VecFloatScale3D(VecFloat3D* that, float a);

// Return a VecFloat equal to (that * a)
#if BUILDMODE != 0
inline
#endif
VecFloat* _VecFloatGetScale(VecFloat* that, float a);
#if BUILDMODE != 0
inline
#endif
VecFloat2D _VecFloatGetScale2D(VecFloat2D* that, float a);
#if BUILDMODE != 0
inline
#endif
VecFloat3D _VecFloatGetScale3D(VecFloat3D* that, float a);

// Calculate (that * a + tho * b) and store the result in 'that'
// 'tho' can be null, in which case it is consider to be the null vector
// If 'tho' is not null it must be of same dimension as 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatOp(VecFloat* that, float a, VecFloat* tho, float b);
#if BUILDMODE != 0
inline
#endif
void _VecFloatOp2D(VecFloat2D* that, float a, VecFloat2D* tho, float b);
#if BUILDMODE != 0
inline
#endif
void _VecFloatOp3D(VecFloat3D* that, float a, VecFloat3D* tho, float b);
```

```
// Return a VecFloat equal to (that * a + tho * b)
// Return NULL if arguments are invalid
// 'tho' can be null, in which case it is consider to be the null vector
// If 'tho' is not null it must be of same dimension as 'that'
#if BUILDMODE != 0
inline
#endif
VecFloat* _VecFloatGetOp(VecFloat* that, float a,
  VecFloat* tho, float b);
#if BUILDMODE != 0
inline
#endif
VecFloat2D _VecFloatGetOp2D(VecFloat2D* that, float a,
  VecFloat2D* tho, float b);
#if BUILDMODE != 0
inline
#endif
VecFloat3D _VecFloatGetOp3D(VecFloat3D* that, float a,
  VecFloat3D* tho, float b);

// Rotate CCW 'that' by 'theta' radians and store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRot2D(VecFloat2D* that, float theta);

// Return a VecFloat2D equal to 'that' rotated CCW by 'theta' radians
#if BUILDMODE != 0
inline
#endif
VecFloat2D _VecFloatGetRot2D(VecFloat2D* that, float theta);

// Rotate right-hand 'that' by 'theta' radians around 'axis' and
// store the result in 'that'
// 'axis' must be normalized
// https://en.wikipedia.org/wiki/Rotation_matrix
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotAxis(VecFloat3D* that, VecFloat3D* axis, float theta);

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around 'axis'
// 'axis' must be normalized
// https://en.wikipedia.org/wiki/Rotation_matrix
VecFloat3D _VecFloatGetRotAxis(VecFloat3D* that, VecFloat3D* axis,
  float theta);

// Rotate right-hand 'that' by 'theta' radians around X and
// store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotX(VecFloat3D* that, float theta);

// Rotate right-hand 'that' by 'theta' radians around Y and
// store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotY(VecFloat3D* that, float theta);
```

```
// Rotate right-hand 'that' by 'theta' radians around Z and
// store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotZ(VecFloat3D* that, float theta);

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around X
VecFloat3D _VecFloatGetRotX(VecFloat3D* that, float theta);

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around Y
VecFloat3D _VecFloatGetRotY(VecFloat3D* that, float theta);

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around Z
VecFloat3D _VecFloatGetRotZ(VecFloat3D* that, float theta);

// Return the dot product of 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
float _VecFloatDotProd(VecFloat* that, VecFloat* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatDotProd2D(VecFloat2D* that, VecFloat2D* tho);
#if BUILDMODE != 0
inline
#endif
float _VecFloatDotProd3D(VecFloat3D* that, VecFloat3D* tho);

// Return the angle of the rotation making 'that' colinear to 'tho'
// 'that' and 'tho' must be normalised
// Return a value in [-PI,PI]
float _VecFloatAngleTo2D(VecFloat2D* that, VecFloat2D* tho);

// Return the conversion of VecFloat 'that' to a VecShort using round()
#if BUILDMODE != 0
inline
#endif
VecShort* VecFloatToShort(VecFloat* that);
#if BUILDMODE != 0
inline
#endif
VecShort2D VecFloatToShort2D(VecFloat2D* that);
#if BUILDMODE != 0
inline
#endif
VecShort3D VecFloatToShort3D(VecFloat3D* that);

// Return the conversion of VecShort 'that' to a VecFloat
#if BUILDMODE != 0
inline
#endif
VecFloat* VecShortToFloat(VecShort* that);
#if BUILDMODE != 0
inline
#endif
VecFloat2D VecShortToFloat2D(VecShort2D* that);
#if BUILDMODE != 0
```

```
inline
#endif
VecFloat3D VecShortToFloat3D(VecShort3D* that);

// Get the max value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
float _VecFloatGetMaxVal(VecFloat* that);

// Get the min value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
float _VecFloatGetMinVal(VecFloat* that);

// Step the values of the vector incrementally by delta from 0
// in the following order (for example) :
// (0.,0.,0.)->(0.,0.,1.)->(0.,0.,2.)->(0.,1.,0.)->(0.,1.,1.)->...
// The upper limit for each value is given by 'bound' (val[i] <= dim[i])
// Return false after all values of 'that' have reached their upper
// limit (in which case 'that''s values are all set back to 0.)
// Return true else
bool _VecFloatStepDelta(VecFloat* that, VecFloat* bound,
  VecFloat* delta);

// Step the values of the vector incrementally by delta
// in the following order (for example) :
// (0.,0.,0.)->(0.,0.,1.)->(0.,0.,2.)->(0.,1.,0.)->(0.,1.,1.)->...
// The lower limit for each value is given by 'from' (val[i] >= from[i])
// The upper limit for each value is given by 'to' (val[i] <= to[i])
// 'that' must be initialised to 'from' before the first call of this
// function
// Return false after all values of 'that' have reached their upper
// limit (in which case 'that''s values are all set back to from)
// Return true else
bool _VecFloatShiftStepDelta(VecFloat* that, VecFloat* from,
  VecFloat* to, VecFloat* delta);

// -------------- MatFloat

// ================= Data structure ===================

// Vector of float values
typedef struct MatFloat {
  // Dimension
  VecShort2D _dim;
  // Values (memorized by columns)
  float _val[0];
} MatFloat;

// ================ Functions declaration ====================

// Create a new MatFloat of dimension 'dim' (nbCol, nbLine)
// Values are initalized to 0.0
MatFloat* MatFloatCreate(VecShort2D* dim);

// Set the MatFloat to the identity matrix
// The matrix must be a square matrix
#if BUILDMODE != 0
inline
#endif
```

```
void _MatFloatSetIdentity(MatFloat* that);

// Clone the MatFloat
MatFloat* _MatFloatClone(MatFloat* that);

// Copy the values of 'w' in 'that' (must have same dimensions)
#if BUILDMODE != 0
inline
#endif
void _MatFloatCopy(MatFloat* that, MatFloat* w);

// Load the MatFloat from the stream
// If the MatFloat is already allocated, it is freed before loading
// Return true upon success, else false
bool _MatFloatLoad(MatFloat** that, FILE* stream);

// Save the MatFloat to the stream
// Return true upon success, else false
bool _MatFloatSave(MatFloat* that, FILE* stream);

// Free the memory used by a MatFloat
// Do nothing if arguments are invalid
void _MatFloatFree(MatFloat** that);

// Print the MatFloat on 'stream' with 'prec' digit precision
// Do nothing if arguments are invalid
void MatFloatPrintln(MatFloat* that, FILE* stream, unsigned int prec);
inline void _MatFloatPrintlnDef(MatFloat* that, FILE* stream) {
  MatFloatPrintln(that, stream, 3);
}

// Return the value at index (col, line) of the MatFloat
// Index starts at 0, index in matrix = line * nbCol + col
#if BUILDMODE != 0
inline
#endif
float _MatFloatGet(MatFloat* that, VecShort2D* index);

// Set the value at index (col, line) of the MatFloat to 'v'
// Index starts at 0, index in matrix = line * nbCol + col
#if BUILDMODE != 0
inline
#endif
void _MatFloatSet(MatFloat* that, VecShort2D* index, float v);

// Return the dimension of the MatFloat
#if BUILDMODE != 0
inline
#endif
VecShort2D* _MatFloatDim(MatFloat* that);

// Return a VecShort2D containing the dimension of the MatFloat
#if BUILDMODE != 0
inline
#endif
VecShort2D _MatFloatGetDim(MatFloat* that);

// Return the inverse matrix of 'that'
// The matrix must be a square matrix
MatFloat* _MatFloatInv(MatFloat* that);

// Return the product of matrix 'that' and vector 'v'
```

```
// Number of columns of 'that' must equal dimension of 'v'
VecFloat* _MatFloatGetProdVecFloat(MatFloat* that, VecFloat* v);

// Return the product of matrix 'that' by matrix 'tho'
// Number of columns of 'that' must equal number of line of 'tho'
MatFloat* _MatFloatGetProdMatFloat(MatFloat* that, MatFloat* tho);

// Return the addition of matrix 'that' with matrix 'tho'
// 'that' and 'tho' must have same dimensions
#if BUILDMODE != 0
inline
#endif
MatFloat* _MatFloatGetAdd(MatFloat* that, MatFloat* tho);

// Add matrix 'that' with matrix 'tho' and store the result in 'that'
// 'that' and 'tho' must have same dimensions
#if BUILDMODE != 0
inline
#endif
void _MatFloatAdd(MatFloat* that, MatFloat* tho);

// Return true if 'that' is equal to 'tho', false else
bool _MatFloatIsEqual(MatFloat* that, MatFloat* tho);

// -------------- Gauss

// ================= Define ==================

// ================= Data structure ===================

// Vector of float values
typedef struct Gauss {
  // Mean
  float _mean;
  // Sigma
  float _sigma;
} Gauss;

// ================ Functions declaration ====================

// Create a new Gauss of mean 'mean' and sigma 'sigma'
// Return NULL if we couldn't create the Gauss
Gauss* GaussCreate(float mean, float sigma);
Gauss GaussCreateStatic(float mean, float sigma);

// Free the memory used by a Gauss
// Do nothing if arguments are invalid
void GaussFree(Gauss **that);

// Return the value of the Gauss 'that' at 'x'
#if BUILDMODE != 0
inline
#endif
float GaussGet(Gauss *that, float x);

// Return a random value according to the Gauss 'that'
// random() must have been called before calling this function
#if BUILDMODE != 0
inline
#endif
float GaussRnd(Gauss *that);
```

```
// -------------- Smoother

// ================= Define ==================

// ================= Data structure ===================

// ================ Functions declaration ====================

// Return the order 1 smooth value of 'x'
// if x < 0.0 return 0.0
// if x > 1.0 return 1.0
#if BUILDMODE != 0
inline
#endif
float SmoothStep(float x);

// Return the order 2 smooth value of 'x'
// if x < 0.0 return 0.0
// if x > 1.0 return 1.0
#if BUILDMODE != 0
inline
#endif
float SmootherStep(float x);

// -------------- Conversion functions

// ================ Functions declaration ====================

// Convert radians to degrees
inline float ConvRad2Deg(float rad) {
  return rad / PBMATH_TWOPI_DIV_360;
}

// Convert degrees to radians
inline float ConvDeg2Rad(float deg) {
  return PBMATH_TWOPI_DIV_360 * deg;
}

// -------------- SysLinEq

// ================= Data structure ===================

// Linear system of equalities
typedef struct SysLinEq {
  // Matrix
  MatFloat* _M;
  // Inverse of the matrix
  MatFloat* _Minv;
  // Vector
  VecFloat* _V;
} SysLinEq;

// ================ Functions declaration ====================

// Create a new SysLinEq with matrix 'm' and vector 'v'
// The dimension of 'v' must be equal to the number of column of 'm'
// If 'v' is null the vector null is used instead
// The matrix 'm' must be a square matrix
// Return NULL if we couldn't create the SysLinEq
SysLinEq* _SLECreate(MatFloat* m, VecFloat* v);

// Free the memory used by the SysLinEq
```

```
// Do nothing if arguments are invalid
void SysLinEqFree(SysLinEq** that);

// Clone the SysLinEq 'that'
// Return NULL if we couldn't clone the SysLinEq
SysLinEq* SysLinEqClone(SysLinEq*  that);

// Solve the SysLinEq _M.x = _V
// Return the solution vector, or null if there is no solution or the
// arguments are invalid
#if BUILDMODE != 0
inline
#endif
VecFloat* SysLinEqSolve(SysLinEq* that);

// Set the matrix of the SysLinEq to a clone of 'm'
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void SysLinEqSetM(SysLinEq* that, MatFloat* m);

// Set the vector of the SysLinEq to a clone of 'v'
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void _SLESetV(SysLinEq* that, VecFloat* v);

// -------------- Usefull basic functions

// ================ Functions declaration ====================

// Return x^y when x and y are int
// to avoid numerical imprecision from (pow(double,double)
// From https://stackoverflow.com/questions/29787310/
// does-pow-work-for-int-data-type-in-c
#if BUILDMODE != 0
inline
#endif
int powi(int base, int exp);

// Compute a^n, faster than std::pow for n<~100
inline float fastpow(float a, int n) {
  double ret = 1.0;
  for (; n--;) ret *= (double)a;
  return (float)ret;
}

// Compute a^2
inline float fsquare(float a) {
  return a * a;
}

// ================ Inliner ====================

#if BUILDMODE != 0
#include "pbmath-inline.c"
#endif


#endif
```

# 3 Code

## 3.1 pbmath.c

```
// ============ PBMATH.C ================

// ================= Include =================

#include "pbmath.h"
#if BUILDMODE == 0
#include "pbmath-inline.c"
#endif

// -------------- VecShort

// ================ Functions implementation ====================

// Create a new Vec of dimension 'dim'
// Values are initalized to 0.0
VecShort* VecShortCreate(int dim) {
#if BUILDMODE == 0
  if (dim <= 0) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "invalid 'dim' (%d)", dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Allocate memory
  VecShort* that = PBErrMalloc(PBMathErr,
    sizeof(VecShort) + sizeof(short) * dim);
  // Set the default values
  that->_dim = dim;
  for (int i = dim; i--;)
    that->_val[i] = 0;
  // Return the new VecShort
  return that;
}

// Clone the VecShort
// Return NULL if we couldn't clone the VecShort
VecShort* _VecShortClone(VecShort* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create a clone
  VecShort* clone = VecShortCreate(that->_dim);
  // Copy the values
  memcpy(clone, that, sizeof(VecShort) + sizeof(short) * that->_dim);
  // Return the clone
  return clone;
}

// Load the VecShort from the stream
// If the VecShort is already allocated, it is freed before loading
// Return true in case of success, else false
bool _VecShortLoad(VecShort** that, FILE* stream) {
#if BUILDMODE == 0
```

```
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // If 'that' is already allocated
  if (*that != NULL)
    // Free memory
    _VecShortFree(that);
  // Read the number of dimension
  int dim;
  int ret = fscanf(stream, "%d", &dim);
  // If we coudln't fscanf
  if (ret == EOF)
    return false;
  // Check the dimension
  if (dim <= 0)
    return false;
  // Allocate memory
  *that = VecShortCreate(dim);
  // Read the values
  for (int i = 0; i < dim; ++i) {
    ret = fscanf(stream, "%hi", (*that)->_val + i);
    // If we coudln't fscanf
    if (ret == EOF)
      return false;
  }
  // Return success code
  return true;
}

// Save the VecShort to the stream
// Return true in case of success, else false
bool _VecShortSave(VecShort* that, FILE* stream) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Save the dimension
  int ret = fprintf(stream, "%d ", that->_dim);
  // If we coudln't fprintf
  if (ret < 0)
    return false;
  // Save the values
  for (int i = 0; i < that->_dim; ++i) {
    ret = fprintf(stream, "%hi ", that->_val[i]);
    // If we coudln't fprintf
    if (ret < 0)
```

```
      return false;
  }
  fprintf(stream, "\n");
  // If we coudln't fprintf
  if (ret < 0)
    return false;
  // Return success code
  return true;
}

// Free the memory used by a VecShort
// Do nothing if arguments are invalid
void _VecShortFree(VecShort** that) {
  // Check argument
  if (that == NULL || *that == NULL)
    return;
  // Free memory
  free(*that);
  *that = NULL;
}

// Print the VecShort on 'stream' with 'prec' digit precision
void _VecShortPrint(VecShort* that, FILE* stream) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Print the values
  fprintf(stream, "<");
  for (int i = 0; i < that->_dim; ++i) {
    fprintf(stream, "%hi", that->_val[i]);
    if (i < that->_dim - 1)
      fprintf(stream, ",");
  }
  fprintf(stream, ">");
}

// Step the values of the vector incrementally by 1 from 0
// in the following order (for example) :
// (0,0,0)->(0,0,1)->(0,0,2)->(0,1,0)->(0,1,1)->...
// The upper limit for each value is given by 'bound' (val[i] < dim[i])
// Return false if all values of 'that' have reached their upper limit
// (in which case 'that''s values are all set back to 0)
// Return true else
bool _VecShortStep(VecShort* that, VecShort* bound) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (bound == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'bound' is null");
```

```
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != bound->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, bound->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable for the returned flag
  bool ret = true;
  // Declare a variable to memorise the dimension currently increasing
  int iDim = that->_dim - 1;
  // Declare a flag for the loop condition
  bool flag = true;
  // Increment
  do {
    ++(that->_val[iDim]);
    if (that->_val[iDim] >= bound->_val[iDim]) {
      that->_val[iDim] = 0;
      --iDim;
    } else {
      flag = false;
    }
  } while (iDim >= 0 && flag == true);
  if (iDim == -1)
    ret = false;
  // Return the flag
  return ret;
}

// Step the values of the vector incrementally by 1 from 0
// in the following order (for example) :
// (0,0,0)->(1,0,0)->(2,0,0)->(0,1,0)->(1,1,0)->...
// The upper limit for each value is given by 'bound' (val[i] < dim[i])
// Return false if all values of 'that' have reached their upper limit
// (in which case 'that''s values are all set back to 0)
// Return true else
bool _VecShortPStep(VecShort* that, VecShort* bound) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (bound == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'bound' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != bound->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, bound->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable for the returned flag
  bool ret = true;
  // Declare a variable to memorise the dimension currently increasing
  int iDim = 0;
  // Declare a flag for the loop condition
```

```
  bool flag = true;
  // Increment
  do {
    ++(that->_val[iDim]);
    if (that->_val[iDim] >= bound->_val[iDim]) {
      that->_val[iDim] = 0;
      ++iDim;
    } else {
      flag = false;
    }
  } while (iDim < that->_dim && flag == true);
  if (iDim == that->_dim)
    ret = false;
  // Return the flag
  return ret;
}

// Step the values of the vector incrementally by 1
// in the following order (for example) :
// (0,0,0)->(0,0,1)->(0,0,2)->(0,1,0)->(0,1,1)->...
// The lower limit for each value is given by 'from' (val[i] >= from[i])
// The upper limit for each value is given by 'to' (val[i] < to[i])
// 'that' must be initialised to 'from' before the first call of this
// function
// Return false if all values of 'that' have reached their upper limit
// (in which case 'that''s values are all set back to from)
// Return true else
bool _VecShortShiftStep(VecShort* that, VecShort* from, VecShort* to) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (from == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'from' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != from->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'from' dimensions don't match (%d==%d)",
      that->_dim, from->_dim);
    PBErrCatch(PBMathErr);
  }
  if (to == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'to' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != to->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'to' dimensions don't match (%d==%d)",
      that->_dim, to->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable for the returned flag
  bool ret = true;
  // Declare a variable to memorise the dimension currently increasing
  int iDim = that->_dim - 1;
  // Declare a flag for the loop condition
```

```
  bool flag = true;
  // Increment
  do {
    ++(that->_val[iDim]);
    if (that->_val[iDim] >= to->_val[iDim]) {
      that->_val[iDim] = from->_val[iDim];
      --iDim;
    } else {
      flag = false;
    }
  } while (iDim >= 0 && flag == true);
  if (iDim == -1)
    ret = false;
  // Return the flag
  return ret;
}

// -------------- VecFloat

// ================ Functions implementation ====================

// Create a new Vec of dimension 'dim'
// Values are initalized to 0.0
VecFloat* VecFloatCreate(int dim) {
#if BUILDMODE == 0
  if (dim <= 0) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "invalid 'dim' (%d)", dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Allocate memory
  VecFloat* that = PBErrMalloc(PBMathErr,
    sizeof(VecFloat) + sizeof(float) * dim);
  // Set the default values
  that->_dim = dim;
  for (int i = dim; i--;)
    that->_val[i] = 0.0;
  // Return the new VecFloat
  return that;
}

// Clone the VecFloat
VecFloat* _VecFloatClone(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create a clone
  VecFloat* clone = VecFloatCreate(that->_dim);
  // Clone the properties
  memcpy(clone, that, sizeof(VecFloat) + sizeof(float) * that->_dim);
  // Return the clone
  return clone;
}

// Load the VecFloat from the stream
// If the VecFloat is already allocated, it is freed before loading
bool _VecFloatLoad(VecFloat** that, FILE* stream) {
```

```
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // If 'that' is already allocated
  if (*that != NULL) {
    // Free memory
    _VecFloatFree(that);
  }
  // Read the number of dimension
  int dim;
  int ret = fscanf(stream, "%d", &dim);
  // If we coudln't fscanf
  if (ret == EOF)
    return false;
  // Check the dimension
  if (dim <= 0)
    return false;
  // Allocate memory
  *that = VecFloatCreate(dim);
  // Read the values
  for (int i = 0; i < dim; ++i) {
    ret = fscanf(stream, "%f", (*that)->_val + i);
    // If we coudln't fscanf
    if (ret == EOF)
      return false;
  }
  // Return success code
  return true;
}

// Save the VecFloat to the stream
// Return true in case of success, else false
bool _VecFloatSave(VecFloat* that, FILE* stream) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Save the dimension
  int ret = fprintf(stream, "%d ", that->_dim);
  // If we coudln't fprintf
  if (ret < 0)
    return false;
  // Save the values
  for (int i = 0; i < that->_dim; ++i) {
    ret = fprintf(stream, "%f ", that->_val[i]);
```

```
    // If we coudln't fprintf
    if (ret < 0)
      return false;
  }
  fprintf(stream, "\n");
  // If we coudln't fprintf
  if (ret < 0)
    return false;
  // Return success code
  return true;
}

// Free the memory used by a VecFloat
// Do nothing if arguments are invalid
void _VecFloatFree(VecFloat** that) {
  // Check argument
  if (that == NULL || *that == NULL)
    return;
  // Free memory
  free(*that);
  *that = NULL;
}

// Print the VecFloat on 'stream' with 'prec' digit precision
// Do nothing if arguments are invalid
void VecFloatPrint(VecFloat* that, FILE* stream, unsigned int prec) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the format string
  char format[100] = {'\0'};
  sprintf(format, "%%.%df", prec);
  // Print the values
  fprintf(stream, "<");
  for (int i = 0; i < that->_dim; ++i) {
    fprintf(stream, format, that->_val[i]);
    if (i < that->_dim - 1)
      fprintf(stream, ",");
  }
  fprintf(stream, ">");
}

// Return the angle of the rotation making 'that' colinear to 'tho'
// 'that' and 'tho' must be normalised
// Return a value in [-PI,PI]
float _VecFloatAngleTo2D(VecFloat2D* that, VecFloat2D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
```

```
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecNorm(that), 1.0)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' is not a normed vector");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecNorm(tho), 1.0)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'tho' is not a normed vector");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the result
  float theta = 0.0;
  // Calculate the angle
  VecFloat2D m = VecFloatCreateStatic2D();
  if (fabs(VecGet(that, 0)) > fabs(VecGet(that, 1))) {
    VecSet(&m, 0,
      (VecGet(tho, 0) + VecGet(tho, 1) * VecGet(that, 1) /
      VecGet(that, 0)) /
      (VecGet(that, 0) + fsquare(VecGet(that, 1)) / VecGet(that, 0)));
    VecSet(&m, 1,
      (VecGet(&m, 0) * VecGet(that, 1) - VecGet(tho, 1)) /
      VecGet(that, 0));
  } else {
    VecSet(&m, 1,
      (VecGet(tho, 0) - VecGet(tho, 1) * VecGet(that, 0) /
      VecGet(that, 1)) /
      (VecGet(that, 1) + fsquare(VecGet(that, 0)) / VecGet(that, 1)));
    VecSet(&m, 0,
      (VecGet(tho, 1) + VecGet(&m, 1) * VecGet(that, 0)) /
      VecGet(that, 1));
  }
  // Due to numerical imprecision m[0] may be slightly out of [-1,1]
  // which makes acos return NaN, prevent this
  if (VecGet(&m, 0) < -1.0)
    theta = PBMATH_PI;
  else if (VecGet(&m, 0) > 1.0)
    theta = 0.0;
  else
    theta = acos(VecGet(&m, 0));
  if (sin(theta) * VecGet(&m, 1) > 0.0)
    theta *= -1.0;
  // Return the result
  return theta;
}

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around 'axis'
// 'axis' must be normalized
// https://en.wikipedia.org/wiki/Rotation_matrix
VecFloat3D _VecFloatGetRotAxis(VecFloat3D* that, VecFloat3D* axis,
  float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
```

```
  if (axis == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'axis' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(axis) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'axis' 's dimension is invalid (%d=3)",
      VecGetDim(axis));
    PBErrCatch(PBMathErr);
  }
  if (ISEQUALF(VecNorm(axis), 1.0) == false) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'axis' is not normalized");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare variable for optimisation
  float cosTheta = cos(theta);
  float sinTheta = sin(theta);
  // Create the rotation matrix
  VecShort2D d = VecShortCreateStatic2D();
  VecSet(&d, 0, 3); VecSet(&d, 1, 3);
  MatFloat* rot = MatFloatCreate(&d);
  VecSet(&d, 0, 0); VecSet(&d, 1, 0);
  float v = cosTheta + fastpow(VecGet(axis, 0), 2) * (1.0 - cosTheta);
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 0);
  v = VecGet(axis, 0) * VecGet(axis, 1) * (1.0 - cosTheta) -
    VecGet(axis, 2) * sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 0);
  v = VecGet(axis, 0) * VecGet(axis, 2) * (1.0 - cosTheta) +
    VecGet(axis, 1) * sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 1);
  v = VecGet(axis, 0) * VecGet(axis, 1) * (1.0 - cosTheta) +
    VecGet(axis, 2) * sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 1);
  v = cosTheta + fastpow(VecGet(axis, 1), 2) * (1.0 - cosTheta);
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 1);
  v = VecGet(axis, 1) * VecGet(axis, 2) * (1.0 - cosTheta) -
    VecGet(axis, 0) * sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 2);
  v = VecGet(axis, 0) * VecGet(axis, 2) * (1.0 - cosTheta) -
    VecGet(axis, 1) * sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 2);
  v = VecGet(axis, 1) * VecGet(axis, 2) * (1.0 - cosTheta) +
    VecGet(axis, 0) * sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 2);
  v = cosTheta + fastpow(VecGet(axis, 2), 2) * (1.0 - cosTheta);
```

```
  MatSet(rot, &d, v);
  // Calculate the result vector
  VecFloat* w = MatGetProdVec(rot, that);
  VecFloat3D res = *(VecFloat3D*)w;
  // Free memory
  VecFree(&w);
  MatFree(&rot);
  // Return the result
  return res;
}

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around X
VecFloat3D _VecFloatGetRotX(VecFloat3D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare variable for optimisation
  float cosTheta = cos(theta);
  float sinTheta = sin(theta);
  // Create the rotation matrix
  VecShort2D d = VecShortCreateStatic2D();
  VecSet(&d, 0, 3); VecSet(&d, 1, 3);
  MatFloat* rot = MatFloatCreate(&d);
  VecSet(&d, 0, 0); VecSet(&d, 1, 0);
  float v = 1.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 0);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 0);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 1);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 1);
  v = cosTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 1);
  v = -sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 2);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 2);
  v = sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 2);
  v = cosTheta;
  MatSet(rot, &d, v);
  // Calculate the result vector
```

```
  VecFloat* w = MatGetProdVec(rot, that);
  VecFloat3D res = *(VecFloat3D*)w;
  // Free memory
  VecFree(&w);
  MatFree(&rot);
  // Return the result
  return res;
}

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around Y
VecFloat3D _VecFloatGetRotY(VecFloat3D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare variable for optimisation
  float cosTheta = cos(theta);
  float sinTheta = sin(theta);
  // Create the rotation matrix
  VecShort2D d = VecShortCreateStatic2D();
  VecSet(&d, 0, 3); VecSet(&d, 1, 3);
  MatFloat* rot = MatFloatCreate(&d);
  VecSet(&d, 0, 0); VecSet(&d, 1, 0);
  float v = cosTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 0);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 0);
  v = sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 1);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 1);
  v = 1.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 1);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 2);
  v = -sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 2);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 2);
  v = cosTheta;
  MatSet(rot, &d, v);
  // Calculate the result vector
  VecFloat* w = MatGetProdVec(rot, that);
  VecFloat3D res = *(VecFloat3D*)w;
```

```
  // Free memory
  VecFree(&w);
  MatFree(&rot);
  // Return the result
  return res;
}

// Return a VecFloat3D equal to 'that' rotated right-hand by 'theta'
// radians around Z
VecFloat3D _VecFloatGetRotZ(VecFloat3D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare variable for optimisation
  float cosTheta = cos(theta);
  float sinTheta = sin(theta);
  // Create the rotation matrix
  VecShort2D d = VecShortCreateStatic2D();
  VecSet(&d, 0, 3); VecSet(&d, 1, 3);
  MatFloat* rot = MatFloatCreate(&d);
  VecSet(&d, 0, 0); VecSet(&d, 1, 0);
  float v = cosTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 0);
  v = -sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 0);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 1);
  v = sinTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 1);
  v = cosTheta;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 1);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 0); VecSet(&d, 1, 2);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 1); VecSet(&d, 1, 2);
  v = 0.0;
  MatSet(rot, &d, v);
  VecSet(&d, 0, 2); VecSet(&d, 1, 2);
  v = 1.0;
  MatSet(rot, &d, v);
  // Calculate the result vector
  VecFloat* w = MatGetProdVec(rot, that);
  VecFloat3D res = *(VecFloat3D*)w;
  // Free memory
  VecFree(&w);
```

```
  MatFree(&rot);
  // Return the result
  return res;
}

// Step the values of the vector incrementally by delta from 0
// in the following order (for example) :
// (0.,0.,0.)->(0.,0.,1.)->(0.,0.,2.)->(0.,1.,0.)->(0.,1.,1.)->...
// The upper limit for each value is given by 'bound' (val[i] <= dim[i])
// Return false after all values of 'that' have reached their upper
// limit (in which case 'that''s values are all set back to 0.)
// Return true else
bool _VecFloatStepDelta(VecFloat* that, VecFloat* bound,
  VecFloat* delta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (bound == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'bound' is null");
    PBErrCatch(PBMathErr);
  }
  if (delta == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'delta' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != bound->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'bound' 's dimensions don't match (%d==%d)",
      that->_dim, bound->_dim);
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != delta->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'delta' 's dimensions don't match (%d==%d)",
      that->_dim, delta->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable for the returned flag
  bool ret = true;
  // Declare a variable to memorise the dimension currently increasing
  int iDim = that->_dim - 1;
  // Declare a flag for the loop condition
  bool flag = true;
  // Increment
  do {
    that->_val[iDim] += delta->_val[iDim];
    if (that->_val[iDim] > bound->_val[iDim] + PBMATH_EPSILON) {
      that->_val[iDim] = 0;
      --iDim;
    } else {
      flag = false;
    }
  } while (iDim >= 0 && flag == true);
  if (iDim == -1)
```

```
    ret = false;
  // Return the flag
  return ret;
}

// Step the values of the vector incrementally by delta
// in the following order (for example) :
// (0.,0.,0.)->(0.,0.,1.)->(0.,0.,2.)->(0.,1.,0.)->(0.,1.,1.)->...
// The lower limit for each value is given by 'from' (val[i] >= from[i])
// The upper limit for each value is given by 'to' (val[i] <= to[i])
// 'that' must be initialised to 'from' before the first call of this
// function
// Return false after all values of 'that' have reached their upper
// limit (in which case 'that''s values are all set back to from)
// Return true else
bool _VecFloatShiftStepDelta(VecFloat* that, VecFloat* from,
  VecFloat* to, VecFloat* delta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (from == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'from' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != from->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'from' dimensions don't match (%d==%d)",
      that->_dim, from->_dim);
    PBErrCatch(PBMathErr);
  }
  if (to == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'to' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != to->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'to' dimensions don't match (%d==%d)",
      that->_dim, to->_dim);
    PBErrCatch(PBMathErr);
  }
  if (delta == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'delta' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != delta->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'delta' dimensions don't match (%d==%d)",
      that->_dim, delta->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable for the returned flag
  bool ret = true;
  // Declare a variable to memorise the dimension currently increasing
  int iDim = that->_dim - 1;
  // Declare a flag for the loop condition
```

```
  bool flag = true;
  // Increment
  do {
    that->_val[iDim] += delta->_val[iDim];
    if (that->_val[iDim] > to->_val[iDim] + PBMATH_EPSILON) {
      that->_val[iDim] = from->_val[iDim];
      --iDim;
    } else {
      flag = false;
    }
  } while (iDim >= 0 && flag == true);
  if (iDim == -1)
    ret = false;
  // Return the flag
  return ret;
}

// -------------- MatFloat

// ================= Define ==================

// ================ Functions implementation ====================

// Create a new MatFloat of dimension 'dim' (nbcol, nbline)
// Values are initalized to 0.0
MatFloat* MatFloatCreate(VecShort2D* dim) {
#if BUILDMODE == 0
  if (dim == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'dim' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Allocate memory
  int d = VecGet(dim, 0) * VecGet(dim, 1);
  MatFloat* that = PBErrMalloc(PBMathErr, sizeof(MatFloat) +
    sizeof(float) * d);
  // Set the dimension
  that->_dim = *dim;
  // Set the default values
  for (int i = d; i--;)
    that->_val[i] = 0.0;
  // Return the new MatFloat
  return that;
}

// Clone the MatFloat
MatFloat* _MatFloatClone(MatFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create a clone
  MatFloat* clone = MatFloatCreate(&(that->_dim));
  // Copy the values
  int d = VecGet(&(that->_dim), 0) * VecGet(&(that->_dim), 1);
  for (int i = d; i--;)
    clone->_val[i] = that->_val[i];
  // Return the clone
```

```
  return clone;
}

// Load the MatFloat from the stream
// If the MatFloat is already allocated, it is freed before loading
// Return true upon success, else false
bool _MatFloatLoad(MatFloat** that, FILE* stream) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // If 'that' is already allocated
  if (*that != NULL)
    // Free memory
    _MatFloatFree(that);
  // Read the number of dimension
  VecShort2D dim = VecShortCreateStatic2D();
  int ret = fscanf(stream, "%hi %hi", dim._val , dim._val + 1);
  // If we coudln't fscanf
  if (ret == EOF)
    return false;
  if (VecGet(&dim, 0) <= 0 || VecGet(&dim, 1) <= 0)
    return false;
  // Allocate memory
  *that = MatFloatCreate(&dim);
  // Read the values
  VecShort2D index = VecShortCreateStatic2D();
  do {
    float v;
    ret = fscanf(stream, "%f", &v);
    // If we coudln't fscanf
    if (ret == EOF)
      return false;
    MatSet(*that, &index, v);
  } while (VecPStep(&index, &dim));
  // Return success code
  return true;
}

// Save the MatFloat to the stream
// Return true upon success, else false
bool _MatFloatSave(MatFloat* that, FILE* stream) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
```

```
  // Save the dimension
  int ret = fprintf(stream, "%hi %hi\n",
    VecGet(&(that->_dim), 0), VecGet(&(that->_dim), 1));
  if (ret < 0)
    return false;
  // Save the values
  VecShort2D index = VecShortCreateStatic2D();
  do {
    ret = fprintf(stream, "%f ", MatGet(that, &index));
    // If we coudln't fprintf
    if (ret < 0)
      return false;
    if (VecGet(&index, 0) == VecGet(&(that->_dim), 0) - 1) {
      ret = fprintf(stream, "\n");
      // If we coudln't fprintf
      if (ret < 0)
        return false;
    }
  } while (VecPStep(&index, &(that->_dim)));
  // Return success code
  return true;
}

// Free the memory used by a MatFloat
// Do nothing if arguments are invalid
void _MatFloatFree(MatFloat** that) {
  // Check argument
  if (that == NULL || *that == NULL)
    return;
  // Free memory
  free(*that);
  *that = NULL;
}

// Print the MatFloat on 'stream' with 'prec' digit precision
// Do nothing if arguments are invalid
void MatFloatPrintln(MatFloat* that, FILE* stream, unsigned int prec) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (stream == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'stream' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the format string
  char format[100] = {'\0'};
  sprintf(format, "%%.%df", prec);
  // Print the values
  fprintf(stream, "[");
  VecShort2D index = VecShortCreateStatic2D();
  do {
    if (VecGet(&index, 1) != 0 || VecGet(&index, 0) != 0)
      fprintf(stream, " ");
    fprintf(stream, format, MatGet(that, &index));
    if (VecGet(&index, 0) < VecGet(&(that->_dim), 0) - 1)
      fprintf(stream, ",");
    if (VecGet(&index, 0) == VecGet(&(that->_dim), 0) - 1) {
```

```
      if (VecGet(&index, 1) == VecGet(&(that->_dim), 1) - 1)
        fprintf(stream, "]");
      fprintf(stream, "\n");
    }
  } while (VecPStep(&index, &(that->_dim)));
}

// Return the inverse matrix of 'that'
// The matrix must be a square matrix
MatFloat* _MatFloatInv(MatFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGet(&(that->_dim), 0) != VecGet(&(that->_dim), 1)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "the matrix is not square (%dx%d)",
      VecGet(&(that->_dim), 0), VecGet(&(that->_dim), 1));
    PBErrCatch(PBMathErr);
  }
  if (VecGet(&(that->_dim), 0) > 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "_MatFloatInv is defined only for matrix of dim <= 3x3 (%dx%d)",
      VecGet(&(that->_dim), 0), VecGet(&(that->_dim), 1));
    PBErrCatch(PBMathErr);
  }
#endif
  // Allocate memory for the result
  MatFloat* res = MatFloatCreate(&(that->_dim));
  // If the matrix is of dimension 1x1
  if (VecGet(&(that->_dim), 0) == 1) {
#if BUILDMODE == 0
    if (that->_val[0] < PBMATH_EPSILON) {
      PBMathErr->_type = PBErrTypeOther;
      sprintf(PBMathErr->_msg, "the matrix is not inversible");
      PBErrCatch(PBMathErr);
    }
#endif
    res->_val[0] = 1.0 / that->_val[0];
  // If the matrix is of dimension 2x2
  } else if (VecGet(&(that->_dim), 0) == 2) {
    float det = that->_val[0] * that->_val[3] -
      that->_val[2] * that->_val[1];
#if BUILDMODE == 0
    if (ISEQUALF(det, 0.0)) {
      PBMathErr->_type = PBErrTypeOther;
      sprintf(PBMathErr->_msg, "the matrix is not inversible");
      PBErrCatch(PBMathErr);
    }
#endif
    res->_val[0] = that->_val[3] / det;
    res->_val[1] = -1.0 * that->_val[1] / det;
    res->_val[2] = -1.0 * that->_val[2] / det;
    res->_val[3] = that->_val[0] / det;
  // Else, the matrix dimension is 3x3
  } else if (VecGet(&(that->_dim), 0) == 3) {
    float det =
      that->_val[0] *
        (that->_val[4] * that->_val[8] -
```

```
        that->_val[5] * that->_val[7]) -
      that->_val[3] *
        (that->_val[1] * that->_val[8] -
        that->_val[2] * that->_val[7]) +
      that->_val[6] *
        (that->_val[1] * that->_val[5] -
        that->_val[2] * that->_val[4]);
#if BUILDMODE == 0
    if (ISEQUALF(det, 0.0)) {
      PBMathErr->_type = PBErrTypeOther;
      sprintf(PBMathErr->_msg, "the matrix is not inversible");
      PBErrCatch(PBMathErr);
    }
#endif
    res->_val[0] = (that->_val[4] * that->_val[8] -
        that->_val[5] * that->_val[7]) / det;
    res->_val[1] = -(that->_val[1] * that->_val[8] -
        that->_val[2] * that->_val[7]) / det;
    res->_val[2] = (that->_val[1] * that->_val[5] -
        that->_val[2] * that->_val[4]) / det;
    res->_val[3] = -(that->_val[3] * that->_val[8] -
        that->_val[5] * that->_val[6]) / det;
    res->_val[4] = (that->_val[0] * that->_val[8] -
        that->_val[2] * that->_val[6]) / det;
    res->_val[5] = -(that->_val[0] * that->_val[5] -
        that->_val[2] * that->_val[3]) / det;
    res->_val[6] = (that->_val[3] * that->_val[7] -
        that->_val[4] * that->_val[6]) / det;
    res->_val[7] = -(that->_val[0] * that->_val[7] -
        that->_val[1] * that->_val[6]) / det;
    res->_val[8] = (that->_val[0] * that->_val[4] -
        that->_val[1] * that->_val[3]) / det;
  }
  // Return the result
  return res;
}

// Return the product of matrix 'that' and vector 'v'
// Number of colum of 'that' must equal dimension of 'v'
VecFloat* _MatFloatGetProdVecFloat(MatFloat* that, VecFloat* v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (v == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'v' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGet(&(that->_dim), 0) != VecGetDim(v)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "the matrix and vector have incompatible dimensions (%d==%d)",
      VecGet(&(that->_dim), 0), VecGetDim(v));
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the index in the matrix
  VecShort2D i = VecShortCreateStatic2D();
  // Allocate memory for the solution
```

```
  VecFloat* ret = VecFloatCreate(VecGet(&(that->_dim), 1));
  // If we could allocate memory
  if (ret != NULL)
    for (VecSet(&i, 0, 0); VecGet(&i, 0) < VecGet(&(that->_dim), 0);
      VecSet(&i, 0, VecGet(&i, 0) + 1))
      for (VecSet(&i, 1, 0); VecGet(&i, 1) < VecGet(&(that->_dim), 1);
        VecSet(&i, 1, VecGet(&i, 1) + 1))
        VecSet(ret, VecGet(&i, 1), VecGet(ret,
          VecGet(&i, 1)) + VecGet(v, VecGet(&i, 0)) * MatGet(that, &i));
  // Return the result
  return ret;
}

// Return the product of matrix 'that' by matrix 'tho'
// Number of columns of 'that' must equal number of line of 'tho'
MatFloat* _MatFloatGetProdMatFloat(MatFloat* that, MatFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGet(&(that->_dim), 0) != VecGet(&(tho->_dim), 1)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "the matrices have incompatible dimensions (%d==%d)",
      VecGet(&(that->_dim), 0), VecGet(&(tho->_dim), 1));
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare 3 variables to memorize the index in the matrix
  VecShort2D i = VecShortCreateStatic2D();
  VecShort2D j = VecShortCreateStatic2D();
  VecShort2D k = VecShortCreateStatic2D();
  // Allocate memory for the solution
  VecSet(&i, 0, VecGet(&(tho->_dim), 0));
  VecSet(&i, 1, VecGet(&(that->_dim), 1));
  MatFloat* ret = MatFloatCreate(&i);
  for (VecSet(&i, 0, 0); VecGet(&i, 0) < VecGet(&(tho->_dim), 0);
    VecSet(&i, 0, VecGet(&i, 0) + 1))
    for (VecSet(&i, 1, 0); VecGet(&i, 1) < VecGet(&(that->_dim), 1);
      VecSet(&i, 1, VecGet(&i, 1) + 1))
      for (VecSet(&j, 0, 0), VecSet(&j, 1, VecGet(&i, 1)),
        VecSet(&k, 0, VecGet(&i, 0)), VecSet(&k, 1, 0);
        VecGet(&j, 0) < VecGet(&(that->_dim), 0);
        VecSet(&j, 0, VecGet(&j, 0) + 1),
        VecSet(&k, 1, VecGet(&k, 1) + 1)) {
        MatSet(ret, &i, MatGet(ret, &i) +
          MatGet(that, &j) * MatGet(tho, &k));
      }
  // Return the result
  return ret;
}

// Return true if 'that' is equal to 'tho', false else
bool _MatFloatIsEqual(MatFloat* that, MatFloat* tho) {
#if BUILDMODE == 0
```

```
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  if (!VecIsEqual(&(that->_dim), &(tho->_dim)))
    return false;
  VecShort2D v = VecShortCreateStatic2D();
  do {
    if (!ISEQUALF(MatGet(that, &v), MatGet(tho, &v)))
      return false;
  } while (VecStep(&v, &(that->_dim)));
  return true;
}

// -------------- Gauss

// ================ Define ==================

// ================ Functions implementation ====================

// Create a new Gauss of mean 'mean' and sigma 'sigma'
// Return NULL if we couldn't create the Gauss
Gauss* GaussCreate(float mean, float sigma) {
  // Allocate memory
  Gauss *that = PBErrMalloc(PBMathErr, sizeof(Gauss));
  // Set properties
  that->_mean = mean;
  that->_sigma = sigma;
  // Return the new Gauss
  return that;
}
Gauss GaussCreateStatic(float mean, float sigma) {
  // Allocate memory
  Gauss that = {._mean = mean, ._sigma = sigma};
  // Return the new Gauss
  return that;
}

// Free the memory used by a Gauss
// Do nothing if arguments are invalid
void GaussFree(Gauss **that) {
  // Check argument
  if (that == NULL || *that == NULL)
    return;
  // Free memory
  free(*that);
  *that = NULL;
}

// -------------- SysLinEq

// ================ Functions implementation ====================

// Create a new SysLinEq with matrix 'm' and vector 'v'
// The dimension of 'v' must be equal to the number of column of 'm'
```

```
// If 'v' is null the vector null is used instead
// The matrix 'm' must be a square matrix
// Return NULL if we couldn't create the SysLinEq
SysLinEq* _SLECreate(MatFloat* m, VecFloat* v) {
#if BUILDMODE == 0
  if (m == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'m' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGet(&(m->_dim), 0) != VecGet(&(m->_dim), 1)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "the matrix is not square (%dx%d)",
      VecGet(&(m->_dim), 0), VecGet(&(m->_dim), 1));
    PBErrCatch(PBMathErr);
  }
  if (v != NULL) {
    if (VecGet(&(m->_dim), 0) != VecGetDim(v)) {
      PBMathErr->_type = PBErrTypeInvalidArg;
      sprintf(PBMathErr->_msg,
        "the matrix and vector have incompatible dimensions (%d==%d)",
        VecGet(&(m->_dim), 0), VecGetDim(v));
      PBErrCatch(PBMathErr);
    }
  }
#endif
  // Allocate memory
  SysLinEq* that = PBErrMalloc(PBMathErr, sizeof(SysLinEq));
  that->_M = MatClone(m);
  that->_Minv = MatInv(that->_M);
  if (v != NULL)
    that->_V = VecClone(v);
  else
    that->_V = VecFloatCreate(VecGet(&(m->_dim), 0));
  if (that->_M == NULL || that->_V == NULL || that->_Minv == NULL) {
#if BUILDMODE == 0
    if (that->_M == NULL) {
      PBMathErr->_type = PBErrTypeOther;
      sprintf(PBMathErr->_msg, "couldn't create the matrix");
      PBErrCatch(PBMathErr);
    }
    if (that->_Minv == NULL) {
      PBMathErr->_type = PBErrTypeOther;
      sprintf(PBMathErr->_msg, "couldn't inverse the matrix");
      PBErrCatch(PBMathErr);
    }
    if (that->_V == NULL) {
      PBMathErr->_type = PBErrTypeOther;
      sprintf(PBMathErr->_msg, "couldn't create the vector");
      PBErrCatch(PBMathErr);
    }
#endif
    SysLinEqFree(&that);
  }
  // Return the new SysLinEq
  return that;
}

// Free the memory used by the SysLinEq
// Do nothing if arguments are invalid
void SysLinEqFree(SysLinEq** that) {
  // Check arguments
```

```
  if (that == NULL || *that == NULL)
    return;
  // Free memory
  MatFree(&((*that)->_M));
  MatFree(&((*that)->_Minv));
  VecFree(&((*that)->_V));
  free(*that);
  *that = NULL;
}

// Clone the SysLinEq 'that'
// Return NULL if we couldn't clone the SysLinEq
SysLinEq* SysLinEqClone(SysLinEq* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable for the result
  SysLinEq* ret = PBErrMalloc(PBMathErr, sizeof(SysLinEq));
  ret->_M = MatClone(that->_M);
  ret->_Minv = MatClone(that->_Minv);
  ret->_V = VecClone(that->_V);
  if (ret->_M == NULL || ret->_V == NULL || ret->_Minv == NULL)
    SysLinEqFree(&ret);
  // Return the new SysLinEq
  return ret;
}
```

## 3.2 pbmath-inline.c

```
// ============ PBMATH_INLINE.C ================

// ================ Functions implementation ====================

// Static constructors for VecShort
#if BUILDMODE != 0
inline
#endif
VecShort2D VecShortCreateStatic2D() {
  VecShort2D v = {._val = {0, 0}, ._dim = 2};
  return v;
}
#if BUILDMODE != 0
inline
#endif
VecShort3D VecShortCreateStatic3D() {
  VecShort3D v = {._val = {0, 0, 0}, ._dim = 3};
  return v;
}
#if BUILDMODE != 0
inline
#endif
VecShort4D VecShortCreateStatic4D() {
```

```
  VecShort4D v = {._val = {0, 0, 0, 0}, ._dim = 4};
  return v;
}

// Return the i-th value of the VecShort
#if BUILDMODE != 0
inline
#endif
short _VecShortGet(VecShort* that, int i) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= that->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<%d)", i,
      that->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  return ((short*)(((void*)that) + sizeof(int)))[i];
}
#if BUILDMODE != 0
inline
#endif
short _VecShortGet2D(VecShort2D* that, int i) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 2) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<2)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  return that->_val[i];
}
#if BUILDMODE != 0
inline
#endif
short _VecShortGet3D(VecShort3D* that, int i) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<3)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  return that->_val[i];
}
#if BUILDMODE != 0
inline
```

```
#endif
short _VecShortGet4D(VecShort4D* that, int i) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 4) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<4)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  return that->_val[i];
}

// Set the i-th value of the VecShort to v
#if BUILDMODE != 0
inline
#endif
void _VecShortSet(VecShort* that, int i, short v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= that->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<%d)", i,
      that->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  ((short*)(((void*)that) + sizeof(int)))[i] = v;
}
#if BUILDMODE != 0
inline
#endif
void _VecShortSet2D(VecShort2D* that, int i, short v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 2) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<2)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  that->_val[i] = v;
}
#if BUILDMODE != 0
inline
#endif
void _VecShortSet3D(VecShort3D* that, int i, short v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
```

```
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<3)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  that->_val[i] = v;
}
#if BUILDMODE != 0
inline
#endif
void _VecShortSet4D(VecShort4D* that, int i, short v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 4) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<4)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  that->_val[i] = v;
}

// Set all values of the vector 'that' to 0
#if BUILDMODE != 0
inline
#endif
void _VecShortSetNull(VecShort* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Set values
  for (int iDim = that->_dim; iDim--;)
    that->_val[iDim] = 0;
}

// Return the dimension of the VecShort
#if BUILDMODE != 0
inline
#endif
int _VecShortGetDim(VecShort* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  return that->_dim;
}
// Return the Hamiltonian distance between the VecShort 'that' and 'tho'
```

```
#if BUILDMODE != 0
inline
#endif
short _VecShortHamiltonDist(VecShort* that, VecShort* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to calculate the distance
  short ret = 0;
  for (int iDim = VecGetDim(that); iDim--;)
    ret += abs(VecGet(that, iDim) - VecGet(tho, iDim));
  // Return the distance
  return ret;
}
#if BUILDMODE != 0
inline
#endif
short _VecShortHamiltonDist2D(VecShort2D* that, VecShort2D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return abs(VecGet(that, 0) - VecGet(tho, 0)) +
    abs(VecGet(that, 1) - VecGet(tho, 1));
}
#if BUILDMODE != 0
inline
#endif
short _VecShortHamiltonDist3D(VecShort3D* that, VecShort3D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
```

```
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return abs(VecGet(that, 0) - VecGet(tho, 0)) +
    abs(VecGet(that, 1) - VecGet(tho, 1)) +
    abs(VecGet(that, 2) - VecGet(tho, 2));
}
#if BUILDMODE != 0
inline
#endif
short _VecShortHamiltonDist4D(VecShort4D* that, VecShort4D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return abs(VecGet(that, 0) - VecGet(tho, 0)) +
    abs(VecGet(that, 1) - VecGet(tho, 1)) +
    abs(VecGet(that, 2) - VecGet(tho, 2)) +
    abs(VecGet(that, 3) - VecGet(tho, 3));
}

// Return true if the VecShort 'that' is equal to 'tho', else false
#if BUILDMODE != 0
inline
#endif
bool _VecShortIsEqual(VecShort* that, VecShort* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  return
    (memcmp(that->_val, tho->_val, sizeof(short) * that->_dim) == 0);
}

// Copy the values of 'tho' in 'that'
#if BUILDMODE != 0
inline
#endif
```

```
void _VecShortCopy(VecShort* that, VecShort* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Copy the values
  memcpy(that->_val, tho->_val, sizeof(short) * that->_dim);
}

// Return the dot product of 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd(VecShort* that, VecShort* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable ot memorise the result
  short res = 0;
  // For each component
  for (int iDim = that->_dim; iDim--;)
    // Calculate the product
    res += VecGet(that, iDim) * VecGet(tho, iDim);
  // Return the result
  return res;
}
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd2D(VecShort2D* that, VecShort2D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
```

```
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  return VecGet(that, 0) * VecGet(tho, 0) +
    VecGet(that, 1) * VecGet(tho, 1);
}
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd3D(VecShort3D* that, VecShort3D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  return VecGet(that, 0) * VecGet(tho, 0) +
    VecGet(that, 1) * VecGet(tho, 1) +
    VecGet(that, 2) * VecGet(tho, 2);
}
#if BUILDMODE != 0
inline
#endif
short _VecShortDotProd4D(VecShort4D* that, VecShort4D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  return VecGet(that, 0) * VecGet(tho, 0) +
    VecGet(that, 1) * VecGet(tho, 1) +
    VecGet(that, 2) * VecGet(tho, 2) +
    VecGet(that, 3) * VecGet(tho, 3);
}

// Static constructors for VecFloat
#if BUILDMODE != 0
inline
#endif
VecFloat2D VecFloatCreateStatic2D() {
  VecFloat2D v = {._val = {0.0, 0.0}, ._dim = 2};
  return v;
}
```

```
#if BUILDMODE != 0
inline
#endif
VecFloat3D VecFloatCreateStatic3D() {
  VecFloat3D v = {._val = {0.0, 0.0, 0.0}, ._dim = 3};
  return v;
}

// Return the i-th value of the VecFloat
#if BUILDMODE != 0
inline
#endif
float _VecFloatGet(VecFloat* that, int i) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= that->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'i' is invalid (0<=%d<%d)", i, that->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the value
  return that->_val[i];
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatGet2D(VecFloat2D* that, int i) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 2) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<2)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the value
  return that->_val[i];
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatGet3D(VecFloat3D* that, int i) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<3)", i);
    PBErrCatch(PBMathErr);
```

```
  }
#endif
  // Return the value
  return that->_val[i];
}

// Set the i-th value of the VecFloat to v
#if BUILDMODE != 0
inline
#endif
void _VecFloatSet(VecFloat* that, int i, float v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= that->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'i' is invalid (0<=%d<%d)", i, that->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Set the value
  that->_val[i] = v;
}
#if BUILDMODE != 0
inline
#endif
void _VecFloatSet2D(VecFloat2D* that, int i, float v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 2) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<2)", i);
    PBErrCatch(PBMathErr);
  }
#endif
  // Set the value
  that->_val[i] = v;
}
#if BUILDMODE != 0
inline
#endif
void _VecFloatSet3D(VecFloat3D* that, int i, float v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (i < 0 || i >= 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'i' is invalid (0<=%d<3)", i);
    PBErrCatch(PBMathErr);
  }
#endif
```

```
  // Set the value
  that->_val[i] = v;
}

// Set all values of the vector 'that' to 0.0
#if BUILDMODE != 0
inline
#endif
void _VecFloatSetNull(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Set values
  for (int iDim = that->_dim; iDim--;)
    that->_val[iDim] = 0.0;
}
#if BUILDMODE != 0
inline
#endif
void _VecFloatSetNull2D(VecFloat2D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Set values
  that->_val[0] = 0.0;
  that->_val[1] = 0.0;
}
#if BUILDMODE != 0
inline
#endif
void _VecFloatSetNull3D(VecFloat3D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Set values
  that->_val[0] = 0.0;
  that->_val[1] = 0.0;
  that->_val[2] = 0.0;
}

// Return the dimension of the VecFloat
#if BUILDMODE != 0
inline
#endif
int _VecFloatGetDim(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
```

```
  }
#endif
  return that->_dim;
}

// Copy the values of 'tho' in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatCopy(VecFloat* that, VecFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Copy the values
  memcpy(that->_val, tho->_val, sizeof(float) * that->_dim);
}

// Return the norm of the VecFloat
#if BUILDMODE != 0
inline
#endif
float _VecFloatNorm(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to calculate the norm
  float ret = 0.0;
  // Calculate the norm
  for (int iDim = that->_dim; iDim--;)
    ret += fsquare(VecGet(that, iDim));
  ret = sqrt(ret);
  // Return the result
  return ret;
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatNorm2D(VecFloat2D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
```

```
  }
#endif
  // Return the result
  return sqrt(fsquare(VecGet(that, 0)) + fsquare(VecGet(that, 1)));
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatNorm3D(VecFloat3D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the result
  return sqrt(fsquare(VecGet(that, 0)) + fsquare(VecGet(that, 1)) +
    fsquare(VecGet(that, 2)));
}

// Normalise the VecFloat
#if BUILDMODE != 0
inline
#endif
void _VecFloatNormalise(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Normalise
  float norm = VecNorm(that);
  for (int iDim = that->_dim; iDim--;)
    VecSet(that, iDim, VecGet(that, iDim) / norm);
}

#if BUILDMODE != 0
inline
#endif
void _VecFloatNormalise2D(VecFloat2D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Normalise
  float norm = _VecFloatNorm2D(that);
  VecSet(that, 0, VecGet(that, 0) / norm);
  VecSet(that, 1, VecGet(that, 1) / norm);
}
#if BUILDMODE != 0
inline
#endif
void _VecFloatNormalise3D(VecFloat3D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
```

```
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Normalise
  float norm = _VecFloatNorm3D(that);
  VecSet(that, 0, VecGet(that, 0) / norm);
  VecSet(that, 1, VecGet(that, 1) / norm);
  VecSet(that, 2, VecGet(that, 2) / norm);
}

// Return the distance between the VecFloat 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
float _VecFloatDist(VecFloat* that, VecFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to calculate the distance
  float ret = 0.0;
  for (int iDim = that->_dim; iDim--;)
    ret += fsquare(VecGet(that, iDim) - VecGet(tho, iDim));
  ret = sqrt(ret);
  // Return the distance
  return ret;
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatDist2D(VecFloat2D* that, VecFloat2D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return sqrt(fsquare(VecGet(that, 0) - VecGet(tho, 0)) +
    fsquare(VecGet(that, 1) - VecGet(tho, 1)));
}
```

```
#if BUILDMODE != 0
inline
#endif
float _VecFloatDist3D(VecFloat3D* that, VecFloat3D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return sqrt(fsquare(VecGet(that, 0) - VecGet(tho, 0)) +
    fsquare(VecGet(that, 1) - VecGet(tho, 1)) +
    fsquare(VecGet(that, 2) - VecGet(tho, 2)));
}

// Return the Hamiltonian distance between the VecFloat 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
float _VecFloatHamiltonDist(VecFloat* that, VecFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to calculate the distance
  float ret = 0.0;
  for (int iDim = that->_dim; iDim--;)
    ret += fabs(VecGet(that, iDim) - VecGet(tho, iDim));
  // Return the distance
  return ret;
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatHamiltonDist2D(VecFloat2D* that, VecFloat2D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
```

```
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return fabs(VecGet(that, 0) - VecGet(tho, 0)) +
    fabs(VecGet(that, 1) - VecGet(tho, 1));
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatHamiltonDist3D(VecFloat3D* that, VecFloat3D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return fabs(VecGet(that, 0) - VecGet(tho, 0)) +
    fabs(VecGet(that, 1) - VecGet(tho, 1)) +
    fabs(VecGet(that, 2) - VecGet(tho, 2));
}

// Return the Pixel distance between the VecFloat 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
float _VecFloatPixelDist(VecFloat* that, VecFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to calculate the distance
  float ret = 0.0;
  for (int iDim = that->_dim; iDim--;)
    ret += fabs(floor(VecGet(that, iDim)) - floor(VecGet(tho, iDim)));
  // Return the distance
  return ret;
}
```

```
#if BUILDMODE != 0
inline
#endif
float _VecFloatPixelDist2D(VecFloat2D* that, VecFloat2D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return fabs(floor(VecGet(that, 0)) - floor(VecGet(tho, 0))) +
    fabs(floor(VecGet(that, 1)) - floor(VecGet(tho, 1)));
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatPixelDist3D(VecFloat3D* that, VecFloat3D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the distance
  return fabs(floor(VecGet(that, 0)) - floor(VecGet(tho, 0))) +
    fabs(floor(VecGet(that, 1)) - floor(VecGet(tho, 1))) +
    fabs(floor(VecGet(that, 2)) - floor(VecGet(tho, 2)));
}

// Return true if the VecFloat 'that' is equal to 'tho', else false
#if BUILDMODE != 0
inline
#endif
bool _VecFloatIsEqual(VecFloat* that, VecFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
```

```
    PBErrCatch(PBMathErr);
  }
#endif
  // For each component
  for (int iDim = that->_dim; iDim--;)
    // If the values of this components are different
    if (!ISEQUALF(VecGet(that, iDim), VecGet(tho, iDim)))
      // Return false
      return false;
  // Return true
  return true;
}

// Calculate (that * a + tho * b) and store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatOp(VecFloat* that, float a, VecFloat* tho, float b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  for (int iDim = that->_dim; iDim--;)
    VecSet(that, iDim,
      a * VecGet(that, iDim) + b * VecGet(tho, iDim));
}
#if BUILDMODE != 0
inline
#endif
void _VecFloatOp2D(VecFloat2D* that, float a, VecFloat2D* tho, float b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecSet(that, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(that, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
}
#if BUILDMODE != 0
inline
#endif
```

```
void _VecFloatOp3D(VecFloat3D* that, float a, VecFloat3D* tho, float b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecSet(that, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(that, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  VecSet(that, 2, a * VecGet(that, 2) + b * VecGet(tho, 2));
}

// Return a VecFloat equal to (that * a + tho * b)
#if BUILDMODE != 0
inline
#endif
VecFloat* _VecFloatGetOp(VecFloat* that, float a,
  VecFloat* tho, float b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  VecFloat* res = VecFloatCreate(that->_dim);
  for (int iDim = that->_dim; iDim--;)
    VecSet(res, iDim,
      a * VecGet(that, iDim) + b * VecGet(tho, iDim));
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecFloat2D _VecFloatGetOp2D(VecFloat2D* that, float a,
  VecFloat2D* tho, float b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
```

```
    PBErrCatch(PBMathErr);
  }
#endif
  VecFloat2D res = VecFloatCreateStatic2D();
  VecSet(&res, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(&res, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecFloat3D _VecFloatGetOp3D(VecFloat3D* that, float a,
  VecFloat3D* tho, float b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecFloat3D res = VecFloatCreateStatic3D();
  VecSet(&res, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(&res, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  VecSet(&res, 2, a * VecGet(that, 2) + b * VecGet(tho, 2));
  return res;
}

// Calculate (that * a) and store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatScale(VecFloat* that, float a) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  for (int iDim = that->_dim; iDim--;)
    VecSet(that, iDim, a * VecGet(that, iDim));
}
#if BUILDMODE != 0
inline
#endif
void _VecFloatScale2D(VecFloat2D* that, float a) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecSet(that, 0, a * VecGet(that, 0));
  VecSet(that, 1, a * VecGet(that, 1));
}
#if BUILDMODE != 0
```

```
inline
#endif
void _VecFloatScale3D(VecFloat3D* that, float a) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecSet(that, 0, a * VecGet(that, 0));
  VecSet(that, 1, a * VecGet(that, 1));
  VecSet(that, 2, a * VecGet(that, 2));
}

// Return a VecFloat equal to (that * a)
#if BUILDMODE != 0
inline
#endif
VecFloat* _VecFloatGetScale(VecFloat* that, float a) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecFloat* res = VecFloatCreate(that->_dim);
  for (int iDim = that->_dim; iDim--;)
    VecSet(res, iDim, a * VecGet(that, iDim));
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecFloat2D _VecFloatGetScale2D(VecFloat2D* that, float a) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecFloat2D res = VecFloatCreateStatic2D();
  VecSet(&res, 0, a * VecGet(that, 0));
  VecSet(&res, 1, a * VecGet(that, 1));
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecFloat3D _VecFloatGetScale3D(VecFloat3D* that, float a) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecFloat3D res = VecFloatCreateStatic3D();
  VecSet(&res, 0, a * VecGet(that, 0));
  VecSet(&res, 1, a * VecGet(that, 1));
```

```
  VecSet(&res, 2, a * VecGet(that, 2));
  return res;
}

// Rotate CCW 'that' by 'theta' radians and store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRot2D(VecFloat2D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 2) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=2)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  *that = _VecFloatGetRot2D(that, theta);
}

// Return a VecFloat2D equal to 'that' rotated CCW by 'theta' radians
#if BUILDMODE != 0
inline
#endif
VecFloat2D _VecFloatGetRot2D(VecFloat2D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 2) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=2)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the result
  VecFloat2D res = VecFloatCreateStatic2D();
  // Declare variable for optimization
  float cosTheta = cos(theta);
  float sinTheta = sin(theta);
  // Calculate the rotation
  VecSet(&res, 0,
    cosTheta * VecGet(that, 0) - sinTheta * VecGet(that, 1));
  VecSet(&res, 1,
    sinTheta * VecGet(that, 0) + cosTheta * VecGet(that, 1));
  // Return the result
  return res;
}

// Return the dot product of 'that' and 'tho'
#if BUILDMODE != 0
inline
#endif
float _VecFloatDotProd(VecFloat* that, VecFloat* tho) {
```

```
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the result
  float res = 0.0;
  // Calculate
  for (int iDim = that->_dim; iDim--;)
    res += that->_val[iDim] * tho->_val[iDim];
  // Return the result
  return res;
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatDotProd2D(VecFloat2D* that, VecFloat2D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  return that->_val[0] * tho->_val[0] + that->_val[1] * tho->_val[1];
}
#if BUILDMODE != 0
inline
#endif
float _VecFloatDotProd3D(VecFloat3D* that, VecFloat3D* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  return that->_val[0] * tho->_val[0] + that->_val[1] * tho->_val[1] +
    that->_val[2] * tho->_val[2];
```

```
}

// Return the conversion of VecFloat 'that' to a VecShort using round()
#if BUILDMODE != 0
inline
#endif
VecShort* VecFloatToShort(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the result
  VecShort* res = VecShortCreate(that->_dim);
  for (int iDim = that->_dim; iDim--;)
    VecSet(res, iDim, SHORT(VecGet(that, iDim)));
  // Return the result
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecShort2D VecFloatToShort2D(VecFloat2D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the result
  VecShort2D res = VecShortCreateStatic2D();
  VecSet(&res, 0, SHORT(VecGet(that, 0)));
  VecSet(&res, 1, SHORT(VecGet(that, 1)));
  // Return the result
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecShort3D VecFloatToShort3D(VecFloat3D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the result
  VecShort3D res = VecShortCreateStatic3D();
  VecSet(&res, 0, SHORT(VecGet(that, 0)));
  VecSet(&res, 1, SHORT(VecGet(that, 1)));
  VecSet(&res, 2, SHORT(VecGet(that, 2)));
  // Return the result
  return res;
}

// Return the conversion of VecShort 'that' to a VecFloat
#if BUILDMODE != 0
inline
```

```
#endif
VecFloat* VecShortToFloat(VecShort* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the result
  VecFloat* res = VecFloatCreate(that->_dim);
  for (int iDim = that->_dim; iDim--;)
    VecSet(res, iDim, (float)VecGet(that, iDim));
  // Return the result
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecFloat2D VecShortToFloat2D(VecShort2D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the result
  VecFloat2D res = VecFloatCreateStatic2D();
  VecSet(&res, 0, (float)VecGet(that, 0));
  VecSet(&res, 1, (float)VecGet(that, 1));
  // Return the result
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecFloat3D VecShortToFloat3D(VecShort3D* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Create the result
  VecFloat3D res = VecFloatCreateStatic3D();
  VecSet(&res, 0, (float)VecGet(that, 0));
  VecSet(&res, 1, (float)VecGet(that, 1));
  VecSet(&res, 2, (float)VecGet(that, 2));
  // Return the result
  return res;
}

// Get the max value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
float _VecFloatGetMaxVal(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
```

```
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the result
  float max = VecGet(that, 0);
  // Search for the maximum value
  for (int i = VecGetDim(that); i-- && i != 0;)
    max = MAX(max, VecGet(that, i));
  // Return the result
  return max;
}

// Get the min value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
float _VecFloatGetMinVal(VecFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the result
  float min = VecGet(that, 0);
  // Search for the minimum value
  for (int i = VecGetDim(that); i-- && i != 0;)
    min = MIN(min, VecGet(that, i));
  // Return the result
  return min;
}

// Set the MatFloat to the identity matrix
// The matrix must be a square matrix
#if BUILDMODE != 0
inline
#endif
void _MatFloatSetIdentity(MatFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGet(&(that->_dim), 0) != VecGet(&(that->_dim), 1)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "the matrix is not square (%dx%d)",
      VecGet(&(that->_dim), 0), VecGet(&(that->_dim), 1));
    PBErrCatch(PBMathErr);
  }
#endif
  // Set the values
  VecShort2D i = VecShortCreateStatic2D();
  do {
    if (VecGet(&i, 0) == VecGet(&i, 1))
      MatSet(that, &i, 1.0);
    else
      MatSet(that, &i, 0.0);
  } while (VecStep(&i, &(that->_dim)));
}
```

```
// Return the addition of matrix 'that' with matrix 'tho'
// 'that' and 'tho' must have same dimensions
#if BUILDMODE != 0
inline
#endif
MatFloat* _MatFloatGetAdd(MatFloat* that, MatFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecIsEqual(MatDim(that), MatDim(tho)) == false) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'that' and 'tho' have different dimensions");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable for the result
  MatFloat* res = MatFloatCreate(MatDim(that));
  // Add each values
  VecShort2D i = VecShortCreateStatic2D();
  do {
    MatSet(res, &i, MatGet(that, &i) + MatGet(tho, &i));
  } while (VecStep(&i, MatDim(that)));
  // Return the result
  return res;
}

// Add matrix 'that' with matrix 'tho' and store the result in 'that'
// 'that' and 'tho' must have same dimensions
#if BUILDMODE != 0
inline
#endif
void _MatFloatAdd(MatFloat* that, MatFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecIsEqual(MatDim(that), MatDim(tho)) == false) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'that' and 'tho' have different dimensions");
    PBErrCatch(PBMathErr);
  }
#endif
  // Add each values
  VecShort2D i = VecShortCreateStatic2D();
```

```
  do {
    MatSet(that, &i, MatGet(that, &i) + MatGet(tho, &i));
  } while (VecStep(&i, MatDim(that)));
}

// Copy the values of 'w' in 'that' (must have same dimensions)
#if BUILDMODE != 0
inline
#endif
void _MatFloatCopy(MatFloat* that, MatFloat* tho) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&(that->_dim), &(tho->_dim))) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'that' and 'tho' have different dimensions (%dx%d==%dx%d)",
      VecGet(&(that->_dim), 0), VecGet(&(that->_dim), 1),
      VecGet(&(tho->_dim), 0), VecGet(&(tho->_dim), 1));
    PBErrCatch(PBMathErr);
  }
#endif
  // Copy the matrix values
  int d = VecGet(&(that->_dim), 0) * VecGet(&(that->_dim), 1);
  memcpy(that->_val, tho->_val, d * sizeof(float));
}

// Return the value at index 'i' (col, line) of the MatFloat
// Index starts at 0, index in matrix = line * nbCol + col
#if BUILDMODE != 0
inline
#endif
float _MatFloatGet(MatFloat* that, VecShort2D* index) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (index == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'index' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGet(index, 0) < 0 ||
    VecGet(index, 0) >= VecGet(&(that->_dim), 0) ||
    VecGet(index, 1) < 0 ||
    VecGet(index, 1) >= VecGet(&(that->_dim), 1)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'index' is invalid (0,0 <= %d,%d < %d,%d)",
      VecGet(index, 0), VecGet(index, 1),
      VecGet(&(that->_dim), 0), VecGet(&(that->_dim), 1));
    PBErrCatch(PBMathErr);
```

```
  }
#endif
  // Return the value
  return that->_val[VecGet(index, 1) * VecGet(&(that->_dim), 0) +
    VecGet(index, 0)];
}

// Set the value at index 'i' (col, line) of the MatFloat to 'v'
// Index starts at 0, index in matrix = line * nbCol + col
#if BUILDMODE != 0
inline
#endif
void _MatFloatSet(MatFloat* that, VecShort2D* index, float v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (index == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'index' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGet(index, 0) < 0 ||
    VecGet(index, 0) >= VecGet(&(that->_dim), 0) ||
    VecGet(index, 1) < 0 ||
    VecGet(index, 1) >= VecGet(&(that->_dim), 1)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg,
      "'index' is invalid (0,0 <= %d,%d < %d,%d)",
      VecGet(index, 0), VecGet(index, 1),
      VecGet(&(that->_dim), 0), VecGet(&(that->_dim), 1));
    PBErrCatch(PBMathErr);
  }
#endif
  // Set the value
  that->_val[VecGet(index, 1) * VecGet(&(that->_dim), 0) +
    VecGet(index, 0)] = v;
}

// Return the dimension of the MatFloat
#if BUILDMODE != 0
inline
#endif
VecShort2D* _MatFloatDim(MatFloat* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the dimension
  return &(that->_dim);
}

// Return a VecShort2D containing the dimension of the MatFloat
#if BUILDMODE != 0
inline
#endif
VecShort2D _MatFloatGetDim(MatFloat* that) {
```

```
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Return the dimension
  return that->_dim;
}

// Return the value of the Gauss 'that' at 'x'
#if BUILDMODE != 0
inline
#endif
float GaussGet(Gauss *that, float x) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Calculate the value
  float a = 1.0 / (that->_sigma * sqrt(2.0 * PBMATH_PI));
  float ret = a * exp(-1.0 * fsquare(x - that->_mean) /
    (2.0 * fsquare(that->_sigma)));
  // Return the value
  return ret;
}

// Return a random value (in ]0.0, 1.0[)according to the
// Gauss distribution 'that'
// random() must have been called before calling this function
#if BUILDMODE != 0
inline
#endif
float GaussRnd(Gauss *that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare variable for calcul
  float v1,v2,s;
  // Calculate the value
  do {
    v1 = (rnd() - 0.5) * 2.0;
    v2 = (rnd() - 0.5) * 2.0;
    s = v1 * v1 + v2 * v2;
  } while (s >= 1.0);
  // Return the value
  float ret = 0.0;
  if (s > PBMATH_EPSILON)
    ret = v1 * sqrt(-2.0 * log(s) / s);
  return ret * that->_sigma + that->_mean;
}

// Return the order 1 smooth value of 'x'
// if x < 0.0 return 0.0
```

```
// if x > 1.0 return 1.0
#if BUILDMODE != 0
inline
#endif
float SmoothStep(float x) {
  if (x > 0.0)
    if (x < 1.0)
      return x * x * (3.0 - 2.0 * x);
    else
      return 1.0;
  else
    return 0.0;
}

// Return the order 2 smooth value of 'x'
// if x < 0.0 return 0.0
// if x > 1.0 return 1.0
#if BUILDMODE != 0
inline
#endif
float SmootherStep(float x) {
  if (x > 0.0)
    if (x < 1.0)
    return x * x * x * (x * (x * 6.0 - 15.0) + 10.0);
    else
      return 1.0;
  else
    return 0.0;
}

// Solve the SysLinEq _M.x = _V
// Return the solution vector, or null if there is no solution or the
// arguments are invalid
#if BUILDMODE != 0
inline
#endif
VecFloat* SysLinEqSolve(SysLinEq* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the solution
  VecFloat* ret = NULL;
  // Calculate the solution
  ret = MatGetProdVec(that->_Minv, that->_V);
  // Return the solution vector
  return ret;
}

// Set the matrix of the SysLinEq to a copy of 'm'
// 'm' must have same dimensions has the current matrix
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void SysLinEqSetM(SysLinEq* that, MatFloat* m) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
```

```
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (m == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'m' is null");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&(m->_dim), &(that->_M->_dim))) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'m' has invalid dimension (%dx%d==%dx%d)",
      VecGet(&(m->_dim), 0), VecGet(&(m->_dim), 1),
      VecGet(&(that->_M->_dim), 0), VecGet(&(that->_M->_dim), 1));
    PBErrCatch(PBMathErr);
  }
#endif
  // Update the matrix values
  MatCopy(that->_M, m);
  // Update the inverse matrix
  MatFree(&(that->_Minv));
  that->_Minv = MatInv(that->_M);
#if BUILDMODE == 0
  if (that->_Minv == NULL) {
    PBMathErr->_type = PBErrTypeOther;
    sprintf(PBMathErr->_msg, "couldn't inverse the matrix");
    PBErrCatch(PBMathErr);
  }
#endif
}

// Set the vector of the SysLinEq to a copy of 'v'
// 'v' must have same dimensions has the current vector
// Do nothing if arguments are invalid
#if BUILDMODE != 0
inline
#endif
void _SLESetV(SysLinEq* that, VecFloat* v) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (v == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'v' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(v) != VecGetDim(that->_V)) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'v' has invalid dimension (%d==%d)",
      VecGetDim(v), VecGetDim(that->_V));
    PBErrCatch(PBMathErr);
  }
#endif
  // Update the vector values
  VecCopy(that->_V, v);
}

// Return x^y when x and y are int
// to avoid numerical imprecision from (pow(double,double)
// From https://stackoverflow.com/questions/29787310/
```

```
// does-pow-work-for-int-data-type-in-c
#if BUILDMODE != 0
inline
#endif
int powi(int base, int exp) {
  // Declare a variable to memorize the result and init to 1
  int res = 1;
  // Loop on exponent
  while (exp) {
    // Do some magic trick
    if (exp & 1)
      res *= base;
    exp /= 2;
    base *= base;
  }
  // Return the result
  return res;
}

// Calculate (that * a + tho * b) and store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecShortOp(VecShort* that, short a, VecShort* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  for (int iDim = that->_dim; iDim--;)
    VecSet(that, iDim,
      a * VecGet(that, iDim) + b * VecGet(tho, iDim));
}
#if BUILDMODE != 0
inline
#endif
void _VecShortOp2D(VecShort2D* that, short a, VecShort2D* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
```

```
  VecSet(that, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(that, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
}
#if BUILDMODE != 0
inline
#endif
void _VecShortOp3D(VecShort3D* that, short a, VecShort3D* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecSet(that, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(that, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  VecSet(that, 2, a * VecGet(that, 2) + b * VecGet(tho, 2));
}
#if BUILDMODE != 0
inline
#endif
void _VecShortOp4D(VecShort4D* that, short a, VecShort4D* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecSet(that, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(that, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  VecSet(that, 2, a * VecGet(that, 2) + b * VecGet(tho, 2));
  VecSet(that, 3, a * VecGet(that, 3) + b * VecGet(tho, 3));
}

// Return a VecShort equal to (that * a + tho * b)
#if BUILDMODE != 0
inline
#endif
VecShort* _VecShortGetOp(VecShort* that, short a,
  VecShort* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
```

```
  if (that->_dim != tho->_dim) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "dimensions don't match (%d==%d)",
      that->_dim, tho->_dim);
    PBErrCatch(PBMathErr);
  }
#endif
  VecShort* res = VecShortCreate(that->_dim);
  for (int iDim = that->_dim; iDim--;)
    VecSet(res, iDim,
      a * VecGet(that, iDim) + b * VecGet(tho, iDim));
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecShort2D _VecShortGetOp2D(VecShort2D* that, short a,
  VecShort2D* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecShort2D res = VecShortCreateStatic2D();
  VecSet(&res, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(&res, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecShort3D _VecShortGetOp3D(VecShort3D* that, short a,
  VecShort3D* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecShort3D res = VecShortCreateStatic3D();
  VecSet(&res, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(&res, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  VecSet(&res, 2, a * VecGet(that, 2) + b * VecGet(tho, 2));
  return res;
}
#if BUILDMODE != 0
inline
#endif
VecShort4D _VecShortGetOp4D(VecShort4D* that, short a,
```

```
  VecShort4D* tho, short b) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (tho == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'tho' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  VecShort4D res = VecShortCreateStatic4D();
  VecSet(&res, 0, a * VecGet(that, 0) + b * VecGet(tho, 0));
  VecSet(&res, 1, a * VecGet(that, 1) + b * VecGet(tho, 1));
  VecSet(&res, 2, a * VecGet(that, 2) + b * VecGet(tho, 2));
  VecSet(&res, 3, a * VecGet(that, 3) + b * VecGet(tho, 3));
  return res;
}

// Get the max value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
short _VecShortGetMaxVal(VecShort* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the result
  short max = VecGet(that, 0);
  // Search for the maximum value
  for (int i = VecGetDim(that); i-- && i != 0;)
    max = MAX(max, VecGet(that, i));
  // Return the result
  return max;
}

// Get the min value in components of the vector 'that'
#if BUILDMODE != 0
inline
#endif
short _VecShortGetMinVal(VecShort* that) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
#endif
  // Declare a variable to memorize the result
  short min = VecGet(that, 0);
  // Search for the minimum value
  for (int i = VecGetDim(that); i-- && i != 0;)
    min = MIN(min, VecGet(that, i));
  // Return the result
  return min;
}
```

```
// Rotate right-hand 'that' by 'theta' radians around 'axis' and
// store the result in 'that'
// 'axis' must be normalized
// https://en.wikipedia.org/wiki/Rotation_matrix
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotAxis(VecFloat3D* that, VecFloat3D* axis, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (axis == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'axis' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(axis) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'axis' 's dimension is invalid (%d=3)",
      VecGetDim(axis));
    PBErrCatch(PBMathErr);
  }
  if (ISEQUALF(VecNorm(axis), 1.0) == false) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'axis' is not normalized");
    PBErrCatch(PBMathErr);
  }
#endif
  *that = _VecFloatGetRotAxis(that, axis, theta);
}

// Rotate right-hand 'that' by 'theta' radians around X and
// store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotX(VecFloat3D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  *that = _VecFloatGetRotX(that, theta);
}
```

```
// Rotate right-hand 'that' by 'theta' radians around Y and
// store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotY(VecFloat3D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  *that = _VecFloatGetRotY(that, theta);
}

// Rotate right-hand 'that' by 'theta' radians around Z and
// store the result in 'that'
#if BUILDMODE != 0
inline
#endif
void _VecFloatRotZ(VecFloat3D* that, float theta) {
#if BUILDMODE == 0
  if (that == NULL) {
    PBMathErr->_type = PBErrTypeNullPointer;
    sprintf(PBMathErr->_msg, "'that' is null");
    PBErrCatch(PBMathErr);
  }
  if (VecGetDim(that) != 3) {
    PBMathErr->_type = PBErrTypeInvalidArg;
    sprintf(PBMathErr->_msg, "'that' 's dimension is invalid (%d=3)",
      VecGetDim(that));
    PBErrCatch(PBMathErr);
  }
#endif
  *that = _VecFloatGetRotZ(that, theta);
}
```

# 4 Makefile

```
#directory
PBERRDIR=../PBErr

# Build mode
# 0: development (max safety, no optimisation)
# 1: release (min safety, optimisation)
# 2: fast and furious (no safety, optimisation)
BUILDMODE=1

include $(PBERRDIR)/Makefile.inc
```

```
INCPATH=-I./ -I$(PBERRDIR)/
BUILDOPTIONS=$(BUILDPARAM) $(INCPATH)

# compiler
COMPILER=gcc

#rules
all : main

main: main.o pberr.o pbmath.o Makefile
$(COMPILER) main.o pberr.o pbmath.o $(LINKOPTIONS) -o main

main.o : main.c $(PBERRDIR)/pberr.h pbmath.h pbmath-inline.c Makefile
$(COMPILER) $(BUILDOPTIONS) -c main.c

pbmath.o : pbmath.c pbmath.h pbmath-inline.c Makefile
$(COMPILER) $(BUILDOPTIONS) -c pbmath.c

pberr.o : $(PBERRDIR)/pberr.c $(PBERRDIR)/pberr.h Makefile
$(COMPILER) $(BUILDOPTIONS) -c $(PBERRDIR)/pberr.c

clean :
rm -rf *.o main

valgrind :
valgrind -v --track-origins=yes --leak-check=full --gen-suppressions=yes --show-leak-kinds=all ./main

unitTest :
main > unitTest.txt; diff unitTest.txt unitTestRef.txt
```

# 5 Unit tests

```
#include <stdlib.h>
#include <stdio.h>
#include <time.h>
#include <string.h>
#include <time.h>
#include <unistd.h>
#include <sys/time.h>
#include "pberr.h"
#include "pbmath.h"

#define RANDOMSEED 0

void UnitTestPowi() {
  int a;
  int n;
  for (n = 1; n <= 5; ++n) {
    for (a = 0; a <= 10; ++a) {
      int b = powi(a, n);
      int c = 1;
      int m = n;
      for (; m--;) c *= a;
      if (b != c) {
        PBMathErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBMathErr->_msg,
          "powi(%d, %d) = %d , %d^%d = %d",
          a, n, b, a, n, c);
        PBErrCatch(PBMathErr);
```

```
      }
    }
  }
  printf("powi OK\n");
}

void UnitTestFastPow() {
  srandom(RANDOMSEED);
  int nbTest = 1000;
  float sumErr = 0.0;
  float maxErr = 0.0;
  int i = nbTest;
  for (; i--;) {
    float a = (rnd() - 0.5) * 1000.0;
    int n = INT(rnd() * 5.0);
    float b = fastpow(a, n);
    float c = pow(a, n);
    float err = fabs(b - c);
    sumErr += err;
    if (maxErr < err)
      maxErr = err;
  }
  float avgErr = sumErr / (float)nbTest;
  printf("average error: %f < %f, max error: %f < %f\n",
    avgErr, PBMATH_EPSILON, maxErr, PBMATH_EPSILON * 10.0);
  if (avgErr >= PBMATH_EPSILON ||
    maxErr >= PBMATH_EPSILON * 10.0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "fastpow NOK");
    PBErrCatch(PBMathErr);
  }
  printf("fastpow OK\n");
}

void UnitTestSpeedFastPow() {
  srandom(RANDOMSEED);
  int nbTest = 1000;
  int i = nbTest;
  clock_t clockBefore = clock();
  for (; i--;) {
    float a = (rnd() - 0.5) * 1000.0;
    int n = INT(rnd() * 5.0);
    float b = fastpow(a, n);
    b = b;
  }
  clock_t clockAfter = clock();
  double timeFastpow = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  for (; i--;) {
    float a = (rnd() - 0.5) * 1000.0;
    int n = INT(rnd() * 5.0);
    float c = pow(a, n);
    c = c;
  }
  clockAfter = clock();
  double timePow = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("fastpow: %fms, pow: %fms\n",
    timeFastpow / (float)nbTest, timePow / (float)nbTest);
```

```
  if (timeFastpow >= timePow) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    PBMathErr->_fatal = false;
    sprintf(PBMathErr->_msg, "speed fastpow NOK");
    PBErrCatch(PBMathErr);
  }
  printf("speed fastpow OK\n");
}

void UnitTestFSquare() {
  srandom(RANDOMSEED);
  int nbTest = 1000;
  for (; nbTest--;) {
    float a = (rnd() - 0.5) * 2000.0;
    float b = fsquare(a);
    float c = a * a;
    if (!ISEQUALF(b, c)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      PBMathErr->_fatal = false;
      sprintf(PBMathErr->_msg,
        "fsquare(%f) = %f , %f*%f = %f",
        a, b, a, a, c);
      PBErrCatch(PBMathErr);
    }
  }
  printf("fsquare OK\n");
}

void UnitTestVecShortCreateFree() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  VecPrint(v, stdout);printf("\n");
  VecPrint(&v2, stdout);printf("\n");
  VecPrint(&v3, stdout);printf("\n");
  VecPrint(&v4, stdout);printf("\n");
  VecFree(&v);
  if (v != NULL) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecShort is not null after VecFree");
    PBErrCatch(PBMathErr);
  }
  printf("VecShortCreateFree OK\n");
}

void UnitTestVecShortClone() {
  VecShort* v = VecShortCreate(5);
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  VecShort* w = VecClone(v);
  if (memcmp(v, w, sizeof(VecShort) + sizeof(short) * 5) != 0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortClone NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("_VecShortClone OK\n");
}

void UnitTestVecShortLoadSave() {
  VecShort* v = VecShortCreate(5);
```

```
VecShort2D v2 = VecShortCreateStatic2D();
VecShort3D v3 = VecShortCreateStatic3D();
VecShort4D v4 = VecShortCreateStatic4D();
for (int i = 5; i--;) VecSet(v, i, i + 1);
for (int i = 2; i--;) VecSet(&v2, i, i + 1);
for (int i = 3; i--;) VecSet(&v3, i, i + 1);
for (int i = 4; i--;) VecSet(&v4, i, i + 1);
FILE* f = fopen("./UnitTestVecShortLoadSave.txt", "w");
if (f == NULL) {
  PBMathErr->_type = PBErrTypeOther;
  sprintf(PBMathErr->_msg,
    "Can't open ./UnitTestVecShortLoadSave.txt for writing");
  PBErrCatch(PBMathErr);
}
if (!VecSave(v, f)) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortSave NOK");
  PBErrCatch(PBMathErr);
}
if (!VecSave(&v2, f)) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortSave NOK");
  PBErrCatch(PBMathErr);
}
if (!VecSave(&v3, f)) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortSave NOK");
  PBErrCatch(PBMathErr);
}
if (!VecSave(&v4, f)) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortSave NOK");
  PBErrCatch(PBMathErr);
}
fclose(f);
VecShort* w = VecShortCreate(2);
f = fopen("./UnitTestVecShortLoadSave.txt", "r");
if (f == NULL) {
  PBMathErr->_type = PBErrTypeOther;
  sprintf(PBMathErr->_msg,
    "Can't open ./UnitTestVecShortLoadSave.txt for reading");
  PBErrCatch(PBMathErr);
}
if (!VecLoad(&w, f)) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortLoad NOK");
  PBErrCatch(PBMathErr);
}
if (memcmp(v, w, sizeof(VecShort) + sizeof(short) * 5) != 0) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortLoadSave NOK");
  PBErrCatch(PBMathErr);
}
if (!VecLoad(&w, f)) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortLoad NOK");
  PBErrCatch(PBMathErr);
}
if (memcmp(&v2, w, sizeof(VecShort) + sizeof(short) * 2) != 0) {
  PBMathErr->_type = PBErrTypeUnitTestFailed;
  sprintf(PBMathErr->_msg, "_VecShortLoadSave NOK");
  PBErrCatch(PBMathErr);
```

```
  }
  if (!VecLoad(&w, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortLoad NOK");
    PBErrCatch(PBMathErr);
  }
  if (memcmp(&v3, w, sizeof(VecShort) + sizeof(short) * 3) != 0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortLoadSave NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecLoad(&w, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortLoad NOK");
    PBErrCatch(PBMathErr);
  }
  if (memcmp(&v4, w, sizeof(VecShort) + sizeof(short) * 4) != 0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortLoadSave NOK");
    PBErrCatch(PBMathErr);
  }
  fclose(f);
  VecFree(&v);
  VecFree(&w);
  int ret = system("cat ./UnitTestVecShortLoadSave.txt");
  printf("_VecShortLoadSave OK\n");
  ret = system("rm ./UnitTestVecShortLoadSave.txt");
  ret = ret;
}

void UnitTestVecShortGetSetDim() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  if (VecGetDim(v) != 5) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortGetDim NOK");
    PBErrCatch(PBMathErr);
  }
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  for (int i = 4; i--;) VecSet(&v4, i, i + 1);
  for (int i = 5; i--;)
    if (v->_val[i] != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortSet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (v2._val[i] != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortSet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (v3._val[i] != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortSet NOK");
      PBErrCatch(PBMathErr);
    }
```

```
  for (int i = 4; i--;)
    if (v4._val[i] != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortSet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 5; i--;)
    if (VecGet(v, i) != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (VecGet(&v2, i) != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (VecGet(&v3, i) != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 4; i--;)
    if (VecGet(&v4, i) != i + 1) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  VecSetNull(v);
  VecSetNull(&v2);
  VecSetNull(&v3);
  VecSetNull(&v4);
  for (int i = 5; i--;)
    if (VecGet(v, i) != 0) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (VecGet(&v2, i) != 0) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (VecGet(&v3, i) != 0) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 4; i--;)
    if (VecGet(&v4, i) != 0) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGet NOK");
      PBErrCatch(PBMathErr);
    }
  VecFree(&v);
  printf("_VecShortGetSetDim OK\n");
}
```

```
void UnitTestVecShortStep() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  VecShort* bv = VecShortCreate(5);
  VecShort2D bv2 = VecShortCreateStatic2D();
  VecShort3D bv3 = VecShortCreateStatic3D();
  VecShort4D bv4 = VecShortCreateStatic4D();
  short b[5] = {2, 3, 4, 5, 6};
  for (int i = 5; i--;) VecSet(bv, i, b[i]);
  for (int i = 2; i--;) VecSet(&bv2, i, b[i]);
  for (int i = 3; i--;) VecSet(&bv3, i, b[i]);
  for (int i = 4; i--;) VecSet(&bv4, i, b[i]);
  int acheck[2 * 3 * 4 * 5 * 6];
  for (int i = 0; i < 2 * 3 * 4 * 5 * 6; ++i)
    acheck[i] = i;
  int iCheck = 0;
  do {
    int a = VecGet(v, 0);
    for (int i = 1; i < VecGetDim(v); ++i)
      a = a * b[i] + VecGet(v, i);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortStep NOK");
      PBErrCatch(PBMathErr);
    }
    ++iCheck;
  } while (VecStep(v, bv));
  iCheck = 0;
  do {
    int a = VecGet(&v2, 0);
    for (int i = 1; i < 2; ++i)
      a = a * b[i] + VecGet(&v2, i);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortStep NOK");
      PBErrCatch(PBMathErr);
    }
    ++iCheck;
  } while (VecStep(&v2, &bv2));
  iCheck = 0;
  do {
    int a = VecGet(&v3, 0);
    for (int i = 1; i < 3; ++i)
      a = a * b[i] + VecGet(&v3, i);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortStep NOK");
      PBErrCatch(PBMathErr);
    }
    ++iCheck;
  } while (VecStep(&v3, &bv3));
  iCheck = 0;
  do {
    int a = VecGet(&v4, 0);
    for (int i = 1; i < 4; ++i)
      a = a * b[i] + VecGet(&v4, i);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortStep NOK");
      PBErrCatch(PBMathErr);
```

```
    }
    ++iCheck;
  } while (VecStep(&v4, &bv4));
  iCheck = 0;
  do {
    int a = VecGet(v, VecGetDim(v) - 1);
    for (int i = VecGetDim(v) - 2; i >= 0; --i)
      a = a * b[i] + VecGet(v, i);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortPStep NOK");
      PBErrCatch(PBMathErr);
    }
    ++iCheck;
  } while (VecPStep(v, bv));
  iCheck = 0;
  do {
    int a = VecGet(&v2, 1);
    a = a * b[0] + VecGet(&v2, 0);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortPStep NOK");
      PBErrCatch(PBMathErr);
    }
    ++iCheck;
  } while (VecPStep(&v2, &bv2));
  iCheck = 0;
  do {
    int a = VecGet(&v3, 2);
    for (int i = 1; i >= 0; --i)
      a = a * b[i] + VecGet(&v3, i);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortPStep NOK");
      PBErrCatch(PBMathErr);
    }
    ++iCheck;
  } while (VecPStep(&v3, &bv3));
  iCheck = 0;
  do {
    int a = VecGet(&v4, 3);
    for (int i = 2; i >= 0; --i)
      a = a * b[i] + VecGet(&v4, i);
    if (a != acheck[iCheck]) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortPStep NOK");
      PBErrCatch(PBMathErr);
    }
    ++iCheck;
  } while (VecPStep(&v4, &bv4));
  VecFree(&v);
  VecFree(&bv);
  printf("UnitTestVecShortStep OK\n");
}

void UnitTestVecShortHamiltonDist() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  VecShort* w = VecShortCreate(5);
  VecShort2D w2 = VecShortCreateStatic2D();
```

```
  VecShort3D w3 = VecShortCreateStatic3D();
  VecShort4D w4 = VecShortCreateStatic4D();
  short b[5] = {-2, -1, 0, 1, 2};
  for (int i = 5; i--;) VecSet(v, i, b[i]);
  for (int i = 2; i--;) VecSet(&v2, i, b[i]);
  for (int i = 3; i--;) VecSet(&v3, i, b[i]);
  for (int i = 4; i--;) VecSet(&v4, i, b[i]);
  for (int i = 5; i--;) VecSet(w, i, b[4 - i] + 1);
  for (int i = 2; i--;) VecSet(&w2, i, b[1 - i] + 1);
  for (int i = 3; i--;) VecSet(&w3, i, b[2 - i] + 1);
  for (int i = 4; i--;) VecSet(&w4, i, b[3 - i] + 1);
  short dist = VecHamiltonDist(v, w);
  if (dist != 13) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortHamiltonDist NOK");
    PBErrCatch(PBMathErr);
  }
  dist = VecHamiltonDist(&v2, &w2);
  if (dist != 2) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortHamiltonDist NOK");
    PBErrCatch(PBMathErr);
  }
  dist = VecHamiltonDist(&v3, &w3);
  if (dist != 5) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortHamiltonDist NOK");
    PBErrCatch(PBMathErr);
  }
  dist = VecHamiltonDist(&v4, &w4);
  if (dist != 8) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortHamiltonDist NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecShortHamiltonDist OK\n");
}

void UnitTestVecShortIsEqual() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  for (int i = 4; i--;) VecSet(&v4, i, i + 1);
  VecShort* w = VecShortCreate(5);
  VecShort2D w2 = VecShortCreateStatic2D();
  VecShort3D w3 = VecShortCreateStatic3D();
  VecShort4D w4 = VecShortCreateStatic4D();
  if (VecIsEqual(v, w)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (VecIsEqual(&v2, &w2)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
```

```
  }
  if (VecIsEqual(&v3, &w3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (VecIsEqual(&v4, &w4)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  for (int i = 5; i--;) VecSet(w, i, i + 1);
  for (int i = 2; i--;) VecSet(&w2, i, i + 1);
  for (int i = 3; i--;) VecSet(&w3, i, i + 1);
  for (int i = 4; i--;) VecSet(&w4, i, i + 1);
  if (!VecIsEqual(v, w)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v2, &w2)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v3, &w3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v4, &w4)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecShortIsEqual OK\n");
}

void UnitTestVecShortCopy() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  for (int i = 4; i--;) VecSet(&v4, i, i + 1);
  VecShort* w = VecShortCreate(5);
  VecShort2D w2 = VecShortCreateStatic2D();
  VecShort3D w3 = VecShortCreateStatic3D();
  VecShort4D w4 = VecShortCreateStatic4D();
  VecCopy(w, v);
  VecCopy(&w2, &v2);
  VecCopy(&w3, &v3);
  VecCopy(&w4, &v4);
  if (!VecIsEqual(v, w)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortCopy NOK");
    PBErrCatch(PBMathErr);
  }
```

```
  if (!VecIsEqual(&v2, &w2)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortCopy NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v3, &w3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortCopy NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v4, &w4)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortCopy NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecShortCopy OK\n");
}

void UnitTestVecShortDotProd() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  VecShort* w = VecShortCreate(5);
  VecShort2D w2 = VecShortCreateStatic2D();
  VecShort3D w3 = VecShortCreateStatic3D();
  VecShort4D w4 = VecShortCreateStatic4D();
  short b[5] = {-2, -1, 0, 1, 2};
  for (int i = 5; i--;) VecSet(v, i, b[i]);
  for (int i = 2; i--;) VecSet(&v2, i, b[i]);
  for (int i = 3; i--;) VecSet(&v3, i, b[i]);
  for (int i = 4; i--;) VecSet(&v4, i, b[i]);
  for (int i = 5; i--;) VecSet(w, i, b[4 - i] + 1);
  for (int i = 2; i--;) VecSet(&w2, i, b[1 - i] + 1);
  for (int i = 3; i--;) VecSet(&w3, i, b[2 - i] + 1);
  for (int i = 4; i--;) VecSet(&w4, i, b[3 - i] + 1);
  short prod = VecDotProd(v, w);
  if (prod != -10) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortDotProd NOK");
    PBErrCatch(PBMathErr);
  }
  prod = VecDotProd(&v2, &w2);
  if (prod != 1) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortDotProd NOK");
    PBErrCatch(PBMathErr);
  }
  prod = VecDotProd(&v3, &w3);
  if (prod != -2) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortDotProd NOK");
    PBErrCatch(PBMathErr);
  }
  prod = VecDotProd(&v4, &w4);
  if (prod != -6) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortDotProd NOK");
    PBErrCatch(PBMathErr);
  }
```

```
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecShortDotProd OK\n");
}

void UnitTestSpeedVecShort() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  int nbTest = 100000;

  srandom(RANDOMSEED);
  int i = nbTest;
  clock_t clockBefore = clock();
  for (; i--;) {
    int j = INT(rnd() * ((float)(VecGetDim(v) - 1) - PBMATH_EPSILON));
    short val = 1;
    VecSet(v, j, val);
    short valb = VecGet(v, j);
    valb = valb;
  }
  clock_t clockAfter = clock();
  double timeV = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  short* array = malloc(sizeof(short) * 5);
  for (; i--;) {
    int j = INT(rnd() * ((float)(VecGetDim(v) - 1) - PBMATH_EPSILON));
    short val = 1;
    array[j] = val;
    short valb = array[j];
    valb = valb;
  }
  clockAfter = clock();
  double timeRef = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("VecShort: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedVecShort NOK");
    PBErrCatch(PBMathErr);
  }

  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  for (; i--;) {
    int j = INT(rnd() * (1.0 - PBMATH_EPSILON));
    short val = 1;
    VecSet(&v2, j, val);
    short valb = VecGet(&v2, j);
    valb = valb;
  }
  clockAfter = clock();
  timeV = ((double)(clockAfter - clockBefore)) /
```

```
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  short array2[2];
  for (; i--;) {
    int j = INT(rnd() * (1.0 - PBMATH_EPSILON));
    short val = 1;
    array2[j] = val;
    short valb = array2[j];
    valb = valb;
  }
  clockAfter = clock();
  timeRef = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("VecShort2D: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedVecShort NOK");
    PBErrCatch(PBMathErr);
  }

  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  for (; i--;) {
    int j = INT(rnd() * (2.0 - PBMATH_EPSILON));
    short val = 1;
    VecSet(&v3, j, val);
    short valb = VecGet(&v3, j);
    valb = valb;
  }
  clockAfter = clock();
  timeV = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  short array3[3];
  for (; i--;) {
    int j = INT(rnd() * (2.0 - PBMATH_EPSILON));
    short val = 1;
    array3[j] = val;
    short valb = array3[j];
    valb = valb;
  }
  clockAfter = clock();
  timeRef = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("VecShort3D: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedVecShort NOK");
    PBErrCatch(PBMathErr);
```

```
  }

  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  for (; i--;) {
    int j = INT(rnd() * (3.0 - PBMATH_EPSILON));
    short val = 1;
    VecSet(&v4, j, val);
    short valb = VecGet(&v4, j);
    valb = valb;
  }
  clockAfter = clock();
  timeV = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  short array4[4];
  for (; i--;) {
    int j = INT(rnd() * (3.0 - PBMATH_EPSILON));
    short val = 1;
    array4[j] = val;
    short valb = array4[j];
    valb = valb;
  }
  clockAfter = clock();
  timeRef = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("VecShort4D: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedVecShort NOK");
    PBErrCatch(PBMathErr);
  }

  VecFree(&v);
  free(array);
  printf("UnitTestSpeedVecShort OK\n");
}

void UnitTestVecShortToFloat() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  for (int i = 4; i--;) VecSet(&v4, i, i + 1);
  VecFloat* w = VecShortToFloat(v);
  VecFloat2D w2 = VecShortToFloat2D(&v2);
  VecFloat3D w3 = VecShortToFloat3D(&v3);
  VecPrint(w, stdout); printf("\n");
  VecPrint(&w2, stdout); printf("\n");
  VecPrint(&w3, stdout); printf("\n");
  VecFree(&v);
  VecFree(&w);
```

```
  printf("UnitTestVecShortToFloat OK\n");
}

void UnitTestVecShortOp() {
  VecShort* v = VecShortCreate(5);
  VecShort2D v2 = VecShortCreateStatic2D();
  VecShort3D v3 = VecShortCreateStatic3D();
  VecShort4D v4 = VecShortCreateStatic4D();
  VecShort* w = VecShortCreate(5);
  VecShort2D w2 = VecShortCreateStatic2D();
  VecShort3D w3 = VecShortCreateStatic3D();
  VecShort4D w4 = VecShortCreateStatic4D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  short a[2] = {-1, 2};
  short b[5] = {-2, -1, 0, 1, 2};
  for (int i = 5; i--;) VecSet(v, i, b[i]);
  for (int i = 2; i--;) VecSet(&v2, i, b[i]);
  for (int i = 3; i--;) VecSet(&v3, i, b[i]);
  for (int i = 4; i--;) VecSet(&v4, i, b[i]);
  for (int i = 5; i--;) VecSet(w, i, b[4 - i] + 1);
  for (int i = 2; i--;) VecSet(&w2, i, b[1 - i] + 1);
  for (int i = 3; i--;) VecSet(&w3, i, b[2 - i] + 1);
  for (int i = 4; i--;) VecSet(&w4, i, b[3 - i] + 1);
  VecShort* u = VecGetOp(v, a[0], w, a[1]);
  VecShort2D u2 = VecGetOp(&v2, a[0], &w2, a[1]);
  VecShort3D u3 = VecGetOp(&v3, a[0], &w3, a[1]);
  VecShort4D u4 = VecGetOp(&v4, a[0], &w4, a[1]);
  short checku[5] = {8,5,2,-1,-4};
  short checku2[2] = {2,-1};
  short checku3[3] = {4,1,-2};
  short checku4[4] = {6,3,0,-3};
  for (int i = 5; i--;)
    if (!ISEQUALF(VecGet(u, i), checku[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGetOp NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (!ISEQUALF(VecGet(&u2, i), checku2[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGetOp NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (!ISEQUALF(VecGet(&u3, i), checku3[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGetOp NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 4; i--;)
    if (!ISEQUALF(VecGet(&u4, i), checku4[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecShortGetOp NOK");
      PBErrCatch(PBMathErr);
    }
  VecOp(v, a[0], w, a[1]);
  VecOp(&v2, a[0], &w2, a[1]);
  VecOp(&v3, a[0], &w3, a[1]);
  VecOp(&v4, a[0], &w4, a[1]);
  if (!VecIsEqual(v, u)) {
```

```
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortOp NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v2, &u2)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortOp NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v3, &u3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortOp NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v4, &u4)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecShortOp NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  VecFree(&u);
  printf("UnitTestVecShortOp OK\n");
}

void UnitTestVecShortShiftStep() {
  VecShort3D v = VecShortCreateStatic3D();
  VecShort3D from = VecShortCreateStatic3D();
  VecShort3D to = VecShortCreateStatic3D();
  VecSet(&from, 0, 0);
  VecSet(&from, 1, 1);
  VecSet(&from, 2, 2);
  VecSet(&to, 0, 3);
  VecSet(&to, 1, 4);
  VecSet(&to, 2, 5);
  VecCopy(&v, &from);
  short check[81] = {
    0, 1, 2, 0, 1, 3, 0, 1, 4,
    0, 2, 2, 0, 2, 3, 0, 2, 4,
    0, 3, 2, 0, 3, 3, 0, 3, 4,
    1, 1, 2, 1, 1, 3, 1, 1, 4,
    1, 2, 2, 1, 2, 3, 1, 2, 4,
    1, 3, 2, 1, 3, 3, 1, 3, 4,
    2, 1, 2, 2, 1, 3, 2, 1, 4,
    2, 2, 2, 2, 2, 3, 2, 2, 4,
    2, 3, 2, 2, 3, 3, 2, 3, 4
    };
  int iCheck = 0;
  do {
    for (int i = 0; i < 3; ++i) {
      if (ISEQUALF(check[iCheck], VecGet(&v, i)) == false) {
        PBMathErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBMathErr->_msg, "VecShiftStep NOK");
        PBErrCatch(PBMathErr);
      }
      ++iCheck;
    }
  } while(VecShiftStep(&v, &from, &to));
  printf("UnitTestVecShortShiftStep OK\n");
}

void UnitTestVecShortGetMinMax() {
```

```
  VecShort2D v = VecShortCreateStatic2D();
  VecSet(&v, 0, 1); VecSet(&v, 1, 2);
  short val = VecGetMaxVal(&v);
  if (val != 2) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecGetMaxVal NOK");
    PBErrCatch(PBMathErr);
  }
  val = VecGetMinVal(&v);
  if (val != 1) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecGetMinVal NOK");
    PBErrCatch(PBMathErr);
  }
  printf("UnitTestVecShortGetMinMax OK\n");
}

void UnitTestVecShort() {
  UnitTestVecShortCreateFree();
  UnitTestVecShortClone();
  UnitTestVecShortLoadSave();
  UnitTestVecShortGetSetDim();
  UnitTestVecShortStep();
  UnitTestVecShortHamiltonDist();
  UnitTestVecShortIsEqual();
  UnitTestVecShortDotProd();
  UnitTestVecShortCopy();
  UnitTestSpeedVecShort();
  UnitTestVecShortToFloat();
  UnitTestVecShortOp();
  UnitTestVecShortShiftStep();
  UnitTestVecShortGetMinMax();
  printf("UnitTestVecShort OK\n");
}

void UnitTestVecFloatCreateFree() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  VecPrint(v, stdout);printf("\n");
  VecPrint(&v2, stdout);printf("\n");
  VecPrint(&v3, stdout);printf("\n");
  _VecFloatFree(&v);
  if (v != NULL) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecFloat is not null after _VecFloatFree");
    PBErrCatch(PBMathErr);
  }
  printf("VecFloatCreateFree OK\n");
}

void UnitTestVecFloatClone() {
  VecFloat* v = VecFloatCreate(5);
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  VecFloat* w = VecClone(v);
  if (memcmp(v, w, sizeof(VecFloat) + sizeof(float) * 5) != 0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatClone NOK");
    PBErrCatch(PBMathErr);
  }
  _VecFloatFree(&v);
  _VecFloatFree(&w);
```

```
  printf("_VecFloatClone OK\n");
}

void UnitTestVecFloatLoadSave() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  FILE* f = fopen("./UnitTestVecFloatLoadSave.txt", "w");
  if (f == NULL) {
    PBMathErr->_type = PBErrTypeOther;
    sprintf(PBMathErr->_msg,
      "Can't open ./UnitTestVecFloatLoadSave.txt for writing");
    PBErrCatch(PBMathErr);
  }
  if (!VecSave(v, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatSave NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecSave(&v2, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatSave NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecSave(&v3, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatSave NOK");
    PBErrCatch(PBMathErr);
  }
  fclose(f);
  VecFloat* w = VecFloatCreate(2);
  f = fopen("./UnitTestVecFloatLoadSave.txt", "r");
  if (f == NULL) {
    PBMathErr->_type = PBErrTypeOther;
    sprintf(PBMathErr->_msg,
      "Can't open ./UnitTestVecFloatLoadSave.txt for reading");
    PBErrCatch(PBMathErr);
  }
  if (!VecLoad(&w, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatLoad NOK");
    PBErrCatch(PBMathErr);
  }
  if (memcmp(v, w, sizeof(VecFloat) + sizeof(float) * 5) != 0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatLoadSave NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecLoad(&w, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatLoad NOK");
    PBErrCatch(PBMathErr);
  }
  if (memcmp(&v2, w, sizeof(VecFloat) + sizeof(float) * 2) != 0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatLoadSave NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecLoad(&w, f)) {
```

```
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatLoad NOK");
    PBErrCatch(PBMathErr);
  }
  if (memcmp(&v3, w, sizeof(VecFloat) + sizeof(float) * 3) != 0) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatLoadSave NOK");
    PBErrCatch(PBMathErr);
  }
  fclose(f);
  VecFree(&v);
  VecFree(&w);
  int ret = system("cat ./UnitTestVecFloatLoadSave.txt");
  printf("_VecFloatLoadSave OK\n");
  ret = system("rm ./UnitTestVecFloatLoadSave.txt");
  ret = ret;
}

void UnitTestVecFloatGetSetDim() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  if (VecGetDim(v) != 5) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatGetDim NOK");
    PBErrCatch(PBMathErr);
  }
  for (int i = 5; i--;) VecSet(v, i, (float)(i + 1));
  for (int i = 2; i--;) VecSet(&v2, i, (float)(i + 1));
  for (int i = 3; i--;) VecSet(&v3, i, (float)(i + 1));
  for (int i = 5; i--;)
    if (!ISEQUALF(v->_val[i], (float)(i + 1))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatSet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (!ISEQUALF(v2._val[i], (float)(i + 1))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatSet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (!ISEQUALF(v3._val[i], (float)(i + 1))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatSet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 5; i--;)
    if (!ISEQUALF(VecGet(v, i), (float)(i + 1))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (!ISEQUALF(VecGet(&v2, i), (float)(i + 1))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (!ISEQUALF(VecGet(&v3, i), (float)(i + 1))) {
```

```
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGet NOK");
      PBErrCatch(PBMathErr);
    }
  VecSetNull(v);
  VecSetNull(&v2);
  VecSetNull(&v3);
  for (int i = 5; i--;)
    if (!ISEQUALF(VecGet(v, i), 0.0)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (!ISEQUALF(VecGet(&v2, i), 0.0)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGet NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (!ISEQUALF(VecGet(&v3, i), 0.0)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGet NOK");
      PBErrCatch(PBMathErr);
    }
  VecFree(&v);
  printf("_VecFloatGetSetDim OK\n");
}

void UnitTestVecFloatCopy() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  VecFloat* w = VecFloatCreate(5);
  VecFloat2D w2 = VecFloatCreateStatic2D();
  VecFloat3D w3 = VecFloatCreateStatic3D();
  VecCopy(w, v);
  VecCopy(&w2, &v2);
  VecCopy(&w3, &v3);
  if (!VecIsEqual(v, w)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatCopy NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v2, &w2)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatCopy NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v3, &w3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatCopy NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecFloatCopy OK\n");
}
```

```
void UnitTestVecFloatNorm() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  if (!ISEQUALF(VecNorm(v), 7.416198)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatNorm NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecNorm(&v2), 2.236068)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatNorm NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecNorm(&v3), 3.741657)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatNorm NOK");
    PBErrCatch(PBMathErr);
  }
  VecNormalise(v);
  VecNormalise(&v2);
  VecNormalise(&v3);
  if (!ISEQUALF(VecNorm(v), 1.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatNormalise NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecNorm(&v2), 1.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatNormalise NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecNorm(&v3), 1.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatNormalise NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  printf("UnitTestVecFloatNorm OK\n");
}

void UnitTestVecFloatDist() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  VecFloat* w = VecFloatCreate(5);
  VecFloat2D w2 = VecFloatCreateStatic2D();
  VecFloat3D w3 = VecFloatCreateStatic3D();
  float b[5] = {-2.0, -1.0, 0.0, 1.0, 2.0};
  for (int i = 5; i--;) VecSet(v, i, b[i]);
  for (int i = 2; i--;) VecSet(&v2, i, b[i]);
  for (int i = 3; i--;) VecSet(&v3, i, b[i]);
  for (int i = 5; i--;) VecSet(w, i, b[4 - i] + 1.5);
  for (int i = 2; i--;) VecSet(&w2, i, b[1 - i] + 1.5);
  for (int i = 3; i--;) VecSet(&w3, i, b[2 - i] + 1.5);
  if (!ISEQUALF(VecDist(v, w), 7.158911)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatDist NOK");
    PBErrCatch(PBMathErr);
```

```
  }
  if (!ISEQUALF(VecDist(&v2, &w2), 2.549510)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatDist NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecDist(&v3, &w3), 3.840573)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatDist NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecHamiltonDist(v, w), 13.5)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatHamiltonDist NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecHamiltonDist(&v2, &w2), 3.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatHamiltonDist NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecHamiltonDist(&v3, &w3), 5.5)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatHamiltonDist NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecPixelDist(v, w), 13.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatPixelDist NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecPixelDist(&v2, &w2), 2.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatPixelDist NOK");
    PBErrCatch(PBMathErr);
  }
  if (!ISEQUALF(VecPixelDist(&v3, &w3), 5.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatPixelDist NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecFloatDist OK\n");
}

void UnitTestVecFloatIsEqual() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  VecFloat* w = VecFloatCreate(5);
  VecFloat2D w2 = VecFloatCreateStatic2D();
  VecFloat3D w3 = VecFloatCreateStatic3D();
  if (VecIsEqual(v, w)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (VecIsEqual(&v2, &w2)) {
```

```
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (VecIsEqual(&v3, &w3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  for (int i = 5; i--;) VecSet(w, i, i + 1);
  for (int i = 2; i--;) VecSet(&w2, i, i + 1);
  for (int i = 3; i--;) VecSet(&w3, i, i + 1);
  if (!VecIsEqual(v, w)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v2, &w2)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v3, &w3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatIsEqual NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecFloatIsEqual OK\n");
}

void UnitTestVecFloatScale() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  float a = 0.1;
  VecFloat* w = VecGetScale(v, a);
  VecFloat2D w2 = VecGetScale(&v2, a);
  VecFloat3D w3 = VecGetScale(&v3, a);
  VecScale(v, a);
  VecScale(&v2, a);
  VecScale(&v3, a);
  for (int i = 5; i--;)
    if (!ISEQUALF(VecGet(w, i), (float)(i + 1) * a)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGetScale NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (!ISEQUALF(VecGet(&w2, i), (float)(i + 1) * a)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGetScale NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (!ISEQUALF(VecGet(&w3, i), (float)(i + 1) * a)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGetScale NOK");
```

```
      PBErrCatch(PBMathErr);
    }
  for (int i = 5; i--;)
    if (!ISEQUALF(VecGet(v, i), (float)(i + 1) * a)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatScale NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (!ISEQUALF(VecGet(&v2, i), (float)(i + 1) * a)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatScale NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
    if (!ISEQUALF(VecGet(&v3, i), (float)(i + 1) * a)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatScale NOK");
      PBErrCatch(PBMathErr);
    }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecFloatScale OK\n");
}

void UnitTestVecFloatOp() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  VecFloat* w = VecFloatCreate(5);
  VecFloat2D w2 = VecFloatCreateStatic2D();
  VecFloat3D w3 = VecFloatCreateStatic3D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  float a[2] = {-0.1, 2.0};
  float b[5] = {-2.0, -1.0, 0.0, 1.0, 2.0};
  for (int i = 5; i--;) VecSet(v, i, b[i]);
  for (int i = 2; i--;) VecSet(&v2, i, b[i]);
  for (int i = 3; i--;) VecSet(&v3, i, b[i]);
  for (int i = 5; i--;) VecSet(w, i, b[4 - i] + 0.5);
  for (int i = 2; i--;) VecSet(&w2, i, b[1 - i] + 0.5);
  for (int i = 3; i--;) VecSet(&w3, i, b[2 - i] + 0.5);
  VecFloat* u = VecGetOp(v, a[0], w, a[1]);
  VecFloat2D u2 = VecGetOp(&v2, a[0], &w2, a[1]);
  VecFloat3D u3 = VecGetOp(&v3, a[0], &w3, a[1]);
  float checku[5] = {5.2,3.1,1.0,-1.1,-3.2};
  float checku2[2] = {-0.8,-2.9};
  float checku3[3] = {1.2,-0.9,-3.0};
  for (int i = 5; i--;)
    if (!ISEQUALF(VecGet(u, i), checku[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGetOp NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 2; i--;)
    if (!ISEQUALF(VecGet(&u2, i), checku2[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGetOp NOK");
      PBErrCatch(PBMathErr);
    }
  for (int i = 3; i--;)
```

```
    if (!ISEQUALF(VecGet(&u3, i), checku3[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "_VecFloatGetOp NOK");
      PBErrCatch(PBMathErr);
    }
  VecOp(v, a[0], w, a[1]);
  VecOp(&v2, a[0], &w2, a[1]);
  VecOp(&v3, a[0], &w3, a[1]);
  if (!VecIsEqual(v, u)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatOp NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v2, &u2)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatOp NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&v3, &u3)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatOp NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  VecFree(&u);
  printf("UnitTestVecFloatOp OK\n");
}

void UnitTestVecFloatDotProd() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  VecFloat* w = VecFloatCreate(5);
  VecFloat2D w2 = VecFloatCreateStatic2D();
  VecFloat3D w3 = VecFloatCreateStatic3D();
  float b[5] = {-2.0, -1.0, 0.0, 1.0, 2.0};
  for (int i = 5; i--;) VecSet(v, i, b[i]);
  for (int i = 2; i--;) VecSet(&v2, i, b[i]);
  for (int i = 3; i--;) VecSet(&v3, i, b[i]);
  for (int i = 5; i--;) VecSet(w, i, b[4 - i] + 1.5);
  for (int i = 2; i--;) VecSet(&w2, i, b[1 - i] + 1.5);
  for (int i = 3; i--;) VecSet(&w3, i, b[2 - i] + 1.5);
  float prod = VecDotProd(v, w);
  if (!ISEQUALF(prod, -10.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatDotProd NOK");
    PBErrCatch(PBMathErr);
  }
  prod = VecDotProd(&v2, &w2);
  if (!ISEQUALF(prod, -0.5)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatDotProd NOK");
    PBErrCatch(PBMathErr);
  }
  prod = VecDotProd(&v3, &w3);
  if (!ISEQUALF(prod, -3.5)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatDotProd NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
```

```
  VecFree(&w);
  printf("UnitTestVecFloatDotProd OK\n");
}

void UnitTestVecFloatRotAngleTo() {
  VecFloat* v = VecFloatCreate(2);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat* w = VecFloatCreate(2);
  VecFloat2D w2 = VecFloatCreateStatic2D();
  VecSet(v, 0, 1.0);
  VecSet(&v2, 0, 1.0);
  VecSet(w, 0, 1.0);
  VecSet(&w2, 0, 1.0);
  float a = 0.0;
  float da = PBMATH_TWOPI_DIV_360;
  for (int i = 360; i--;) {
    VecRot(v, da);
    VecNormalise(v);
    VecRot(&v2, da);
    VecNormalise(&v2);
    a += da;
    if (ISEQUALF(a, PBMATH_PI)) {
      a = -PBMATH_PI;
      if (!ISEQUALF(fabs(VecAngleTo(w, v)), fabs(a))) {
        PBMathErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBMathErr->_msg, "_VecFloatAngleTo NOK");
        PBErrCatch(PBMathErr);
      }
      if (!ISEQUALF(fabs(VecAngleTo(&w2, &v2)), fabs(a))) {
        PBMathErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBMathErr->_msg, "_VecFloatAngleTo NOK");
        PBErrCatch(PBMathErr);
      }
    } else {
      if (!ISEQUALF(VecAngleTo(w, v), a)) {
        PBMathErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBMathErr->_msg, "_VecFloatAngleTo NOK");
        PBErrCatch(PBMathErr);
      }
      if (!ISEQUALF(VecAngleTo(&w2, &v2), a)) {
        PBMathErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBMathErr->_msg, "_VecFloatAngleTo NOK");
        PBErrCatch(PBMathErr);
      }
    }
  }
  VecSet(v, 0, 1.0);
  VecSet(v, 1, 0.0);
  VecRot(v, PBMATH_QUARTERPI);
  if (!ISEQUALF(VecGet(v, 0), 0.70711) ||
    !ISEQUALF(VecGet(v, 1), 0.70711)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_VecFloatRot NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecFloatAngleTo OK\n");
}

void UnitTestVecFloatToShort() {
  VecFloat* v = VecFloatCreate(5);
```

```
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  for (int i = 5; i--;) VecSet(v, i, i + 1);
  for (int i = 2; i--;) VecSet(&v2, i, i + 1);
  for (int i = 3; i--;) VecSet(&v3, i, i + 1);
  VecShort* w = VecFloatToShort(v);
  VecShort2D w2 = VecFloatToShort2D(&v2);
  VecShort3D w3 = VecFloatToShort3D(&v3);
  VecPrint(w, stdout); printf("\n");
  VecPrint(&w2, stdout); printf("\n");
  VecPrint(&w3, stdout); printf("\n");
  VecFree(&v);
  VecFree(&w);
  printf("UnitTestVecFloatToShort OK\n");
}

void UnitTestSpeedVecFloat() {
  VecFloat* v = VecFloatCreate(5);
  VecFloat2D v2 = VecFloatCreateStatic2D();
  VecFloat3D v3 = VecFloatCreateStatic3D();
  int nbTest = 100000;

  srandom(RANDOMSEED);
  int i = nbTest;
  clock_t clockBefore = clock();
  for (; i--;) {
    int j = INT(rnd() * ((float)(VecGetDim(v) - 1) - PBMATH_EPSILON));
    float val = 1.0;
    VecSet(v, j, val);
    float valb = VecGet(v, j);
    valb = valb;
  }
  clock_t clockAfter = clock();
  double timeV = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  float* array = malloc(sizeof(float) * 5);
  for (; i--;) {
    int j = INT(rnd() * ((float)(VecGetDim(v) - 1) - PBMATH_EPSILON));
    float val = 1.0;
    array[j] = val;
    float valb = array[j];
    valb = valb;
  }
  clockAfter = clock();
  double timeRef = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("VecFloat: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedVecFloat NOK");
    PBErrCatch(PBMathErr);
  }

  srandom(RANDOMSEED);
  i = nbTest;
```

```
  clockBefore = clock();
  for (; i--;) {
    int j = INT(rnd() * (1.0 - PBMATH_EPSILON));
    float val = 1.0;
    VecSet(&v2, j, val);
    float valb = VecGet(&v2, j);
    valb = valb;
  }
  clockAfter = clock();
  timeV = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  float array2[2];
  for (; i--;) {
    int j = INT(rnd() * (1.0 - PBMATH_EPSILON));
    float val = 1.0;
    array2[j] = val;
    float valb = array2[j];
    valb = valb;
  }
  clockAfter = clock();
  timeRef = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("VecFloat2D: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedVecFloat NOK");
    PBErrCatch(PBMathErr);
  }

  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  for (; i--;) {
    int j = INT(rnd() * (2.0 - PBMATH_EPSILON));
    float val = 1.0;
    VecSet(&v3, j, val);
    float valb = VecGet(&v3, j);
    valb = valb;
  }
  clockAfter = clock();
  timeV = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  float array3[3];
  for (; i--;) {
    int j = INT(rnd() * (2.0 - PBMATH_EPSILON));
    float val = 1.0;
    array3[j] = val;
    float valb = array3[j];
    valb = valb;
  }
  clockAfter = clock();
  timeRef = ((double)(clockAfter - clockBefore)) /
```

```
    CLOCKS_PER_SEC * 1000.0;
  printf("VecFloat3D: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedVecFloat NOK");
    PBErrCatch(PBMathErr);
  }
  VecFree(&v);
  free(array);
  printf("UnitTestSpeedVecFloat OK\n");
}

void UnitTestVecFloatRotAxis() {
  VecFloat3D v = VecFloatCreateStatic3D();
  VecSet(&v, 0, 1.0); VecSet(&v, 1, 0.0); VecSet(&v, 2, 1.0);
  VecFloat3D axis = VecFloatCreateStatic3D();
  VecSet(&axis, 0, 1.0); VecSet(&axis, 1, 1.0); VecSet(&axis, 2, 1.0);
  VecNormalise(&axis);
  float theta = PBMATH_PI;
  VecRotAxis(&v, &axis, theta);
  if (!ISEQUALF(VecGet(&v, 0), 0.333333) ||
    !ISEQUALF(VecGet(&v, 1), 1.333333) ||
    !ISEQUALF(VecGet(&v, 2), 0.333333)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecRotAxis NOK");
    PBErrCatch(PBMathErr);
  }
  theta = PBMATH_HALFPI;
  VecRotAxis(&v, &axis, theta);
  if (!ISEQUALF(VecGet(&v, 0), 0.089316) ||
    !ISEQUALF(VecGet(&v, 1), 0.666666) ||
    !ISEQUALF(VecGet(&v, 2), 1.244017)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecRotAxis NOK");
    PBErrCatch(PBMathErr);
  }
  VecSet(&v, 0, 1.0); VecSet(&v, 1, 1.0); VecSet(&v, 2, 1.0);
  theta = PBMATH_PI;
  VecRotX(&v, theta);
  if (!ISEQUALF(VecGet(&v, 0), 1.0) ||
    !ISEQUALF(VecGet(&v, 1), -1.0) ||
    !ISEQUALF(VecGet(&v, 2), -1.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecRotX NOK");
    PBErrCatch(PBMathErr);
  }
  VecSet(&v, 0, 1.0); VecSet(&v, 1, 1.0); VecSet(&v, 2, 1.0);
  theta = PBMATH_PI;
  VecRotY(&v, theta);
  if (!ISEQUALF(VecGet(&v, 0), -1.0) ||
    !ISEQUALF(VecGet(&v, 1), 1.0) ||
    !ISEQUALF(VecGet(&v, 2), -1.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecRotY NOK");
    PBErrCatch(PBMathErr);
  }
  VecSet(&v, 0, 1.0); VecSet(&v, 1, 1.0); VecSet(&v, 2, 1.0);
  theta = PBMATH_PI;
```

```
  VecRotZ(&v, theta);
  if (!ISEQUALF(VecGet(&v, 0), -1.0) ||
    !ISEQUALF(VecGet(&v, 1), -1.0) ||
    !ISEQUALF(VecGet(&v, 2), 1.0)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecRotZ NOK");
    PBErrCatch(PBMathErr);
  }
  printf("UnitTestVecFloatRotAxis OK\n");
}

void UnitTestVecFloatGetMinMax() {
  VecFloat2D v = VecFloatCreateStatic2D();
  VecSet(&v, 0, 1.0); VecSet(&v, 1, 2.0);
  float val = VecGetMaxVal(&v);
  if (ISEQUALF(val, 2.0) == false) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecGetMaxVal NOK");
    PBErrCatch(PBMathErr);
  }
  val = VecGetMinVal(&v);
  if (ISEQUALF(val, 1.0) == false) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "VecGetMinVal NOK");
    PBErrCatch(PBMathErr);
  }
  printf("UnitTestVecFloatGetMinMax OK\n");
}

void UnitTestVecFloat() {
  UnitTestVecFloatCreateFree();
  UnitTestVecFloatClone();
  UnitTestVecFloatLoadSave();
  UnitTestVecFloatGetSetDim();
  UnitTestVecFloatCopy();
  UnitTestVecFloatNorm();
  UnitTestVecFloatDist();
  UnitTestVecFloatIsEqual();
  UnitTestVecFloatScale();
  UnitTestVecFloatOp();
  UnitTestVecFloatDotProd();
  UnitTestVecFloatRotAngleTo();
  UnitTestVecFloatToShort();
  UnitTestVecFloatGetMinMax();
  UnitTestVecFloatRotAxis();
  UnitTestSpeedVecFloat();
  printf("UnitTestVecFloat OK\n");
}

void UnitTestMatFloatCreateFree() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  for (int i = VecGet(&dim, 0) * VecGet(&dim, 1);i--;) {
    if (!ISEQUALF(mat->_val[i], 0.0)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatCreateFree NOK");
      PBErrCatch(PBMathErr);
    }
  }
  MatFree(&mat);
```

```
  if (mat != NULL) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "mat is not null after MatFree");
    PBErrCatch(PBMathErr);
  }
  printf("UnitTestMatFloatCreateFree OK\n");
}

void UnitTestMatFloatGetSetDim() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  if (!VecIsEqual(&(mat->_dim), &dim)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestMatFloatGetSetDim NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(MatDim(mat), &dim)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestMatFloatGetSetDim NOK");
    PBErrCatch(PBMathErr);
  }
  VecShort2D i = VecShortCreateStatic2D();
  float v = 1.0;
  do {
    MatSet(mat, &i, v);
    v += 1.0;
  } while(VecStep(&i, &dim));
  v = 1.0;
  for (int j = 0; j < VecGet(&dim, 0); ++j) {
    for (int k = 0; k < VecGet(&dim, 1); ++k) {
      if (!ISEQUALF(mat->_val[k * VecGet(&dim, 0) + j], v)) {
        PBMathErr->_type = PBErrTypeUnitTestFailed;
        sprintf(PBMathErr->_msg, "UnitTestMatFloatGetSetDim NOK");
        PBErrCatch(PBMathErr);
      }
      v += 1.0;
    }
  }
  VecSetNull(&i);
  v = 1.0;
  do {
    float w = MatGet(mat, &i);
    if (!ISEQUALF(v, w)) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatGetSetDim NOK");
      PBErrCatch(PBMathErr);
    }
    v += 1.0;
  } while(VecStep(&i, &dim));
  MatFree(&mat);
  printf("UnitTestMatFloatGetSetDim OK\n");
}

void UnitTestMatFloatCloneIsEqual() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  VecShort2D i = VecShortCreateStatic2D();
  float v = 1.0;
```

```
  do {
    MatSet(mat, &i, v);
    v += 1.0;
  } while(VecStep(&i, &dim));
  MatFloat* clone = MatClone(mat);
  if (!VecIsEqual(&(mat->_dim), &(clone->_dim))) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestMatFloatClone NOK");
    PBErrCatch(PBMathErr);
  }
  VecSetNull(&i);
  do {
    if (!ISEQUALF(MatGet(mat, &i), MatGet(clone, &i))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatClone NOK");
      PBErrCatch(PBMathErr);
    }
  } while(VecStep(&i, &dim));
  if (MatIsEqual(mat, clone) == false) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestMatFloatIsEqual NOK1");
    PBErrCatch(PBMathErr);
  }
  VecSet(&i, 0, 0); VecSet(&i, 1, 0);
  MatSet(clone, &i, -1.0);
  if (MatIsEqual(mat, clone) == true) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestMatFloatIsEqual NOK2");
    PBErrCatch(PBMathErr);
  }
  MatFree(&mat);
  MatFree(&clone);
  printf("UnitTestMatFloatCloneIsEqual OK\n");
}

void UnitTestMatFloatLoadSave() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  VecShort2D i = VecShortCreateStatic2D();
  float v = 1.0;
  do {
    MatSet(mat, &i, v);
    v += 1.0;
  } while(VecStep(&i, &dim));
  FILE* f = fopen("./UnitTestMatFloatLoadSave.txt", "w");
  if (f == NULL) {
    PBMathErr->_type = PBErrTypeOther;
    sprintf(PBMathErr->_msg,
      "Can't open ./UnitTestMatFloatLoadSave.txt for writing");
    PBErrCatch(PBMathErr);
  }
  if (!MatSave(mat, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_MatFloatSave NOK");
    PBErrCatch(PBMathErr);
  }
  fclose(f);
  MatFloat* clone = MatFloatCreate(&dim);
  f = fopen("./UnitTestMatFloatLoadSave.txt", "r");
  if (f == NULL) {
```

```
    PBMathErr->_type = PBErrTypeOther;
    sprintf(PBMathErr->_msg,
      "Can't open ./UnitTestMatFloatLoadSave.txt for reading");
    PBErrCatch(PBMathErr);
  }
  if (!MatLoad(&clone, f)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "_MatFloatLoad NOK");
    PBErrCatch(PBMathErr);
  }
  if (!VecIsEqual(&(mat->_dim), &(clone->_dim))) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestMatFloatLoadSave NOK");
    PBErrCatch(PBMathErr);
  }
  VecSetNull(&i);
  do {
    if (!ISEQUALF(MatGet(mat, &i), MatGet(clone, &i))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatLoadSave NOK");
      PBErrCatch(PBMathErr);
    }
  } while(VecStep(&i, &dim));
  fclose(f);
  MatFree(&mat);
  MatFree(&clone);
  int ret = system("cat ./UnitTestMatFloatLoadSave.txt");
  ret = system("rm ./UnitTestMatFloatLoadSave.txt");
  ret = ret;
  printf("UnitTestMatFloatLoadSave OK\n");
}

void UnitTestMatFloatInv() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 3);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  VecShort2D i = VecShortCreateStatic2D();
  float v[9] = {3.0, 2.0, 0.0, 0.0, 0.0, 1.0, 2.0, -2.0, 1.0};
  int j = 0;
  do {
    MatSet(mat, &i, v[j]);
    ++j;
  } while(VecStep(&i, &dim));
  MatFloat* inv = MatInv(mat);
  float w[9] = {0.2, -0.2, 0.2, 0.2, 0.3, -0.3, 0.0, 1.0, 0.0};
  VecSetNull(&i);
  j = 0;
  do {
    if (!ISEQUALF(MatGet(inv, &i), w[j])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatInv NOK");
      PBErrCatch(PBMathErr);
    }
    ++j;
  } while(VecStep(&i, &dim));
  MatFree(&mat);
  MatFree(&inv);
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 2);
  mat = MatFloatCreate(&dim);
  float vb[4] = {4.0, 2.0, 7.0, 6.0};
```

```
  VecSetNull(&i);
  j = 0;
  do {
    MatSet(mat, &i, vb[j]);
    ++j;
  } while(VecStep(&i, &dim));
  inv = MatInv(mat);
  float wb[4] = {0.6, -0.2, -0.7, 0.4};
  VecSetNull(&i);
  j = 0;
  do {
    if (!ISEQUALF(MatGet(inv, &i), wb[j])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatInv NOK");
      PBErrCatch(PBMathErr);
    }
    ++j;
  } while(VecStep(&i, &dim));
  MatFree(&mat);
  MatFree(&inv);
  printf("UnitTestMatFloatInv OK\n");
}

void UnitTestMatFloatProdVecFloat() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  VecShort2D i = VecShortCreateStatic2D();
  float v = 1.0;
  do {
    MatSet(mat, &i, v);
    v += 1.0;
  } while(VecStep(&i, &dim));
  VecFloat2D u = VecFloatCreateStatic2D();
  for (int j = 2; j--;)
    VecSet(&u, j, (float)j + 1.0);
  VecFloat* w = MatGetProdVec(mat, &u);
  float b[3] = {9.0, 12.0, 15.0};
  for (int j = 3; j--;) {
    if (!ISEQUALF(VecGet(w, j), b[j])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatProdVecFloat NOK");
      PBErrCatch(PBMathErr);
    }
  }
  MatFree(&mat);
  VecFree(&w);
  printf("UnitTestMatFloatProdVecFloat OK\n");
}

void UnitTestMatFloatProdMatFloat() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 3);
  VecSet(&dim, 1, 2);
  MatFloat* mat = MatFloatCreate(&dim);
  VecShort2D i = VecShortCreateStatic2D();
  float v = 1.0;
  do {
    MatSet(mat, &i, v);
    v += 1.0;
  } while(VecStep(&i, &dim));
```

```
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 3);
  MatFloat* matb = MatFloatCreate(&dim);
  VecSetNull(&i);
  v = 1.0;
  do {
    MatSet(matb, &i, v);
    v += 1.0;
  } while(VecStep(&i, &dim));
  MatFloat* matc = MatGetProdMat(mat, matb);
  float w[4] = {22.0, 28.0, 49.0, 64.0};
  VecSetNull(&i);
  int j = 0;
  VecSet(&dim, 0, 2);
  VecSet(&dim, 1, 2);
  if (!VecIsEqual(&dim, &(matc->_dim))) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestMatFloatProdMatFloat NOK");
    PBErrCatch(PBMathErr);
  }
  do {
    if (!ISEQUALF(MatGet(matc, &i), w[j])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestMatFloatProdMatFloat NOK");
      PBErrCatch(PBMathErr);
    }
    ++j;
  } while(VecStep(&i, &dim));
  MatFree(&mat);
  MatFree(&matb);
  MatFree(&matc);
  printf("UnitTestMatFloatProdMatFloat OK\n");
}

void UnitTestSpeedMatFloat() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 3);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  int nbTest = 100000;
  srandom(RANDOMSEED);
  int i = nbTest;
  clock_t clockBefore = clock();
  VecShort2D j = VecShortCreateStatic2D();
  for (; i--;) {
    float val = 1.0;
    MatSet(mat, &j, val);
    float valb = MatGet(mat, &j);
    valb = valb;
    VecStep(&j, &dim);
  }
  clock_t clockAfter = clock();
  double timeV = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  srandom(RANDOMSEED);
  i = nbTest;
  clockBefore = clock();
  float* array = malloc(sizeof(float) * 9);
  short *ptr = j._val;
  for (; i--;) {
    float val = 1.0;
    int k = ptr[1] * 3 + ptr[0];
```

```
    array[k] = val;
    float valb = array[k];
    valb = valb;
    VecStep(&j, &dim);
  }
  clockAfter = clock();
  double timeRef = ((double)(clockAfter - clockBefore)) /
    CLOCKS_PER_SEC * 1000.0;
  printf("MatFloat: %fms, array: %fms\n",
    timeV / (float)nbTest, timeRef / (float)nbTest);
  if (timeV / (float)nbTest > 2.0 * timeRef / (float)nbTest) {
#if BUILDMODE == 0
    PBMathErr->_fatal = false;
#endif
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestSpeedMatFloat NOK");
    PBErrCatch(PBMathErr);
  }
  MatFree(&mat);
  free(array);
  printf("UnitTestSpeedMatFloat OK\n");
}

void UnitTestMatFloat() {
  UnitTestMatFloatCreateFree();
  UnitTestMatFloatGetSetDim();
  UnitTestMatFloatCloneIsEqual();
  UnitTestMatFloatLoadSave();
  UnitTestMatFloatInv();
  UnitTestMatFloatProdVecFloat();
  UnitTestMatFloatProdMatFloat();
  UnitTestSpeedMatFloat();
  printf("UnitTestMatFloat OK\n");
}

void UnitTestSysLinEq() {
  VecShort2D dim = VecShortCreateStatic2D();
  VecSet(&dim, 0, 3);
  VecSet(&dim, 1, 3);
  MatFloat* mat = MatFloatCreate(&dim);
  float a[9] = {2.0, 2.0, 6.0, 1.0, 6.0, 8.0, 3.0, 8.0, 18.0};
  VecShort2D index = VecShortCreateStatic2D();
  int j = 0;
  do {
    MatSet(mat, &index, a[j]);
    ++j;
  } while(VecStep(&index, &dim));
  VecFloat3D v = VecFloatCreateStatic3D();
  float b[3] = {1.0, 3.0, 5.0};
  for (int i = 3; i--;)
    VecSet(&v, i, b[i]);
  SysLinEq* sys = SysLinEqCreate(mat, &v);
  VecFloat* res = SysLinEqSolve(sys);
  float c[3] = {0.3, 0.4, 0};
  for (int i = 3; i--;) {
    if (!ISEQUALF(c[i], VecGet(res, i))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "SysLinEqSolve NOK");
      PBErrCatch(PBMathErr);
    }
  }
  float ab[9] = {3.0, 2.0, -1.0, 2.0, -2.0, 0.5, -1.0, 4.0, -1.0};
```

```
  VecSetNull(&index);
  j = 0;
  do {
    MatSet(mat, &index, ab[j]);
    ++j;
  } while(VecStep(&index, &dim));
  SysLinEqSetM(sys, mat);
  float bb[3] = {1.0, -2.0, 0.0};
  for (int i = 3; i--;)
    VecSet(&v, i, bb[i]);
  SysLinEqSetV(sys, &v);
  VecFree(&res);
  res = SysLinEqSolve(sys);
  float cb[3] = {1.0, -2.0, -2.0};
  for (int i = 3; i--;) {
    if (!ISEQUALF(cb[i], VecGet(res, i))) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "SysLinEqSolve NOK");
      PBErrCatch(PBMathErr);
    }
  }
  VecFree(&res);
  SysLinEqFree(&sys);
  if (sys != NULL) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "sys is not null after free");
    PBErrCatch(PBMathErr);
  }
  MatFree(&mat);
  printf("UnitTestSysLinEq OK\n");
}

void UnitTestGauss() {
  srandom(RANDOMSEED);
  float mean = 1.0;
  float sigma = 0.5;
  Gauss *gauss = GaussCreate(mean, sigma);
  if (!ISEQUALF(gauss->_mean, mean) ||
    !ISEQUALF(gauss->_sigma, sigma)) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestGaussCreate NOK");
    PBErrCatch(PBMathErr);
  }
  float a[22] = {0.000268, 0.001224, 0.004768, 0.015831, 0.044789,
    0.107982, 0.221842, 0.388372, 0.579383, 0.736540, 0.797885,
    0.736540, 0.579383, 0.388372, 0.221842, 0.107982, 0.044789,
    0.015831, 0.004768, 0.001224, 0.000268};
  for (int i = -5; i<= 15; ++i) {
    if (!ISEQUALF(GaussGet(gauss, (float)i * 0.2), a[i + 5])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestGaussGet NOK");
      PBErrCatch(PBMathErr);
    }
  }
  int nbsample = 1000000;
  double sum = 0.0;
  double sumsquare = 0.0;
  for (int i = nbsample; i--;) {
    float v = GaussRnd(gauss);
    sum += v;
    sumsquare += fsquare(v);
  }
```

```
  double avg = sum / (double)nbsample;
  double sig = sqrtf(sumsquare / (double)nbsample - fsquare(avg));
  if (fabs(avg - mean) > 0.001 ||
    fabs(sig - sigma) > 0.001) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "UnitTestGaussRnd NOK");
    PBErrCatch(PBMathErr);
  }
  GaussFree(&gauss);
  if (gauss != NULL) {
    PBMathErr->_type = PBErrTypeUnitTestFailed;
    sprintf(PBMathErr->_msg, "gauss is not null after free");
    PBErrCatch(PBMathErr);
  }
  printf("UnitTestGauss OK\n");
}

void UnitTestSmoother() {
  float smooth[11] = {0.0, 0.028, 0.104, 0.216, 0.352, 0.5, 0.648,
    0.784, 0.896, 0.972, 1.0};
  float smoother[11] = {0.0, 0.00856, 0.05792, 0.16308, 0.31744, 0.5,
    0.68256, 0.83692, 0.94208, 0.99144, 1.0};
  for (int i = 0; i <= 10; ++i) {
    if (!ISEQUALF(SmoothStep((float)i * 0.1), smooth[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestSmooth NOK");
      PBErrCatch(PBMathErr);
    }
    if (!ISEQUALF(SmootherStep((float)i * 0.1), smoother[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestSmoother NOK");
      PBErrCatch(PBMathErr);
    }
  }
  printf("UnitTestSmoother OK\n");
}

void UnitTestConv() {
  float rad[5] = {0.0, PBMATH_TWOPI, PBMATH_PI, PBMATH_HALFPI, 3.0 * PBMATH_HALFPI};
  float deg[5] = {0.0, 360.0, 180.0, 90.0, 270.0};
  for (int i = 5; i--;) {
    if (!ISEQUALF(ConvRad2Deg(rad[i]), deg[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestConvRad2Deg NOK");
      PBErrCatch(PBMathErr);
    }
    if (!ISEQUALF(ConvDeg2Rad(deg[i]), rad[i])) {
      PBMathErr->_type = PBErrTypeUnitTestFailed;
      sprintf(PBMathErr->_msg, "UnitTestConvDeg2Rad NOK");
      PBErrCatch(PBMathErr);
    }
  }
  printf("UnitTestConv OK\n");
}

void UnitTestBasicFunctions() {
  UnitTestConv();
  UnitTestPowi();
  UnitTestFastPow();
  UnitTestSpeedFastPow();
  UnitTestFSquare();
  UnitTestConv();
```

```
  printf("UnitTestBasicFunctions OK\n");
}

void UnitTestAll() {
  UnitTestVecShort();
  UnitTestVecFloat();
  UnitTestMatFloat();
  UnitTestSysLinEq();
  UnitTestGauss();
  UnitTestSmoother();
  UnitTestBasicFunctions();
  printf("UnitTestAll OK\n");
}

int main() {
  UnitTestAll();
  // Return success code
  return 0;
}
```

# 6 Unit tests output

```
5 1 2 3 4 5
2 1 2
3 1 2 3
4 1 2 3 4
5 1.000000 2.000000 3.000000 4.000000 5.000000
2 1.000000 2.000000
3 1.000000 2.000000 3.000000
2 3
1.000000 4.000000
2.000000 5.000000
3.000000 6.000000
<0,0,0,0,0>
<0,0>
<0,0,0>
<0,0,0,0>
VecShortCreateFree OK
_VecShortClone OK
_VecShortLoadSave OK
_VecShortGetSetDim OK
UnitTestVecShortStep OK
UnitTestVecShortHamiltonDist OK
UnitTestVecShortIsEqual OK
UnitTestVecShortDotProd OK
UnitTestVecShortCopy OK
VecShort: 0.000042ms, array: 0.000034ms
VecShort2D: 0.000014ms, array: 0.000014ms
VecShort3D: 0.000014ms, array: 0.000014ms
VecShort4D: 0.000013ms, array: 0.000013ms
UnitTestSpeedVecShort OK
<1.000,2.000,3.000,4.000,5.000>
<1.000,2.000>
<1.000,2.000,3.000>
UnitTestVecShortToFloat OK
UnitTestVecShortOp OK
UnitTestVecShortShiftStep OK
UnitTestVecShortGetMinMax OK
```

```
UnitTestVecShort OK
<0.000,0.000,0.000,0.000,0.000>
<0.000,0.000>
<0.000,0.000,0.000>
VecFloatCreateFree OK
_VecFloatClone OK
_VecFloatLoadSave OK
_VecFloatGetSetDim OK
UnitTestVecFloatCopy OK
UnitTestVecFloatNorm OK
UnitTestVecFloatDist OK
UnitTestVecFloatIsEqual OK
UnitTestVecFloatScale OK
UnitTestVecFloatOp OK
UnitTestVecFloatDotProd OK
UnitTestVecFloatAngleTo OK
<1,2,3,4,5>
<1,2>
<1,2,3>
UnitTestVecFloatToShort OK
UnitTestVecFloatGetMinMax OK
UnitTestVecFloatRotAxis OK
VecFloat: 0.000031ms, array: 0.000029ms
VecFloat2D: 0.000013ms, array: 0.000013ms
VecFloat3D: 0.000013ms, array: 0.000013ms
UnitTestSpeedVecFloat OK
UnitTestVecFloat OK
UnitTestMatFloatCreateFree OK
UnitTestMatFloatGetSetDim OK
UnitTestMatFloatCloneIsEqual OK
UnitTestMatFloatLoadSave OK
UnitTestMatFloatInv OK
UnitTestMatFloatProdVecFloat OK
UnitTestMatFloatProdMatFloat OK
MatFloat: 0.000006ms, array: 0.000006ms
UnitTestSpeedMatFloat OK
UnitTestMatFloat OK
UnitTestSysLinEq OK
UnitTestGauss OK
UnitTestSmoother OK
UnitTestConv OK
powi OK
average error: 0.000000 < 0.000010, max error: 0.000000 < 0.000100
fastpow OK
fastpow: 0.000024ms, pow: 0.000075ms
speed fastpow OK
fsquare OK
UnitTestConv OK
UnitTestBasicFunctions OK
UnitTestAll OK
```

# 7 Examples

vecshort.txt:

```
3 0 1 0
```

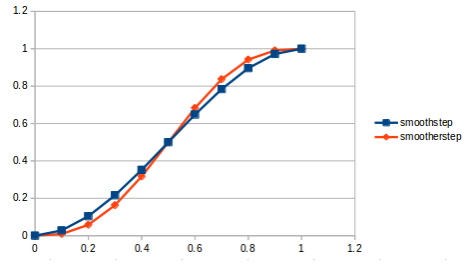
vecfloat.txt:

```
3 0.000000 1.000000 0.000000
```

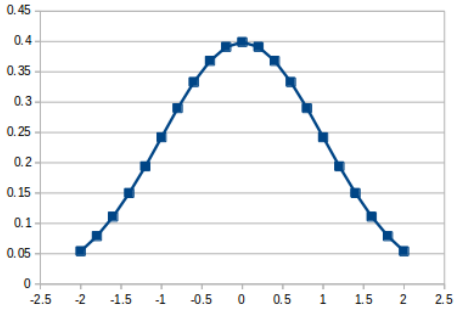
matfloat.txt:

```
3 2
0.500000 2.000000 0.000000
2.000000 0.000000 1.000000
```

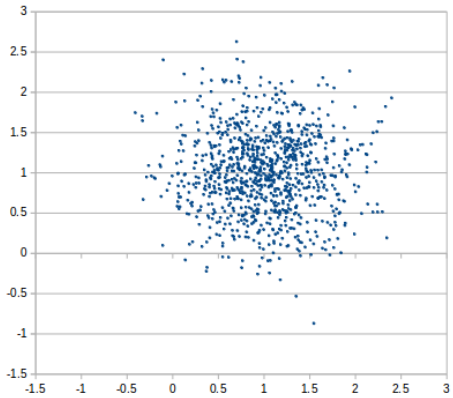
smoother functions:




gauss function (mean:0.0, sigma:1.0):




gauss rand function (mean:1.0, sigma:0.5):


3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3