

Shapoid

P. Baillehache

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Introduction

Shapoid is a C library providing the **Shapoid** structure and its functions which can be used to manipulate Shapoid objects (see next section for details).

It also provides the **ShapoidIter** structure and its functions which can be used to sequentially loop through the surface/volume/... of a **Shapoid**.

It uses the **PBErr**, **PBMath** and **GSet** libraries.

1 Definitions

A Shapoid is a geometry defined by its dimension $D \in \mathbb{N}_+^*$ equals to the number of dimensions of the space it exists in, its position \vec{P} , and its axis $(\vec{A}_0, \vec{A}_1, \dots, \vec{A}_{D-1})$. A_i and P are vectors of dimension D . In what follows I'll use I as notation for the interval $[0, D - 1]$ for simplification.

Shapoids are classified in three groups: Facoid, Pyramidoid and Spheroid. The volume of a Shapoid is defined by, for a Facoid:

$$\left\{ \sum_{i \in I} v_i \vec{A}_i + \vec{P} \right\}, v_i \in [0.0, 1.0] \quad (1)$$

for a Pyramidoid:

$$\left\{ \sum_{i \in I} v_i \vec{A}_i + \vec{P} \right\}, v_i \in [0.0, 1.0], \sum_{i \in I} v_i \leq 1.0 \quad (2)$$

and for a Spheroid:

$$\left\{ \sum_{i \in I} v_i \vec{A}_i + \vec{P} \right\}, \quad v_i \in [-0.5, 0.5], \sum_{i \in I} v_i^2 \leq 0.25 \quad (3)$$

1.1 Transformation

A translation of a Shapoid by \vec{T} is obtained as follow:

$$(\vec{P}, \{\vec{A}_i\}_{i \in I}) \mapsto (\vec{P} + \vec{T}, \{\vec{A}_i\}_{i \in I}) \quad (4)$$

A scale of a Shapoid by \vec{S} is obtained as follow:

$$(\vec{P}, \{\vec{A}_i\}_{i \in I}) \mapsto (\vec{P}, \{\vec{A}'_i\}_{i \in I}) \quad (5)$$

where

$$\vec{A}'_i = S_i \vec{A}_i \quad (6)$$

For Shapoid whose dimension D is equal to 2, a rotation by angle θ is obtained as follow:

$$(\vec{P}, \vec{A}_0, \vec{A}_1) \mapsto (\vec{P}, \vec{A}'_0, \vec{A}'_1) \quad (7)$$

where

$$\vec{A}'_i = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \vec{A}_i \quad (8)$$

1.2 Shapoid's coordinate system

The Shapoid's coordinate system is the system having \vec{P} as origin and \vec{A}_i as axis. One can change from the Shapoid's coordinate system (\vec{X}^S) to the standard coordinate system (\vec{X}) as follow:

$$\vec{X} = \left[\left(\vec{A}_0 \right) \left(\vec{A}_1 \right) \dots \left(\vec{A}_{D-1} \right) \right] \vec{X}^S + \vec{P} \quad (9)$$

and reciprocally, from the standard coordinate system to the Shapoid's coordinate system:

$$\vec{X}^S = \left[\left(\vec{A}_0 \right) \left(\vec{A}_1 \right) \dots \left(\vec{A}_{D-1} \right) \right]^{-1} (\vec{X} - \vec{P}) \quad (10)$$

1.3 Insideness

\vec{X} is inside the Shapoid S if, for a Facoid:

$$\forall i \in I, 0.0 \leq X_i^S \leq 1.0 \quad (11)$$

for a Pyramidoid:

$$\begin{cases} \forall i \in I, 0.0 \leq X_i^S \leq 1.0 \\ \sum_{i \in I} X_i^S \leq 1.0 \end{cases} \quad (12)$$

for a Spheroid:

$$\left\| \vec{X}^S \right\| \leq 0.5 \quad (13)$$

1.4 Bounding box

A bounding box of a Shapoid is a Facoid whose axis are colinear to axis of the standard coordinate system, and including the Shapoid in its volume. While the smallest possible bounding box can be easily obtained for Facoid and Pyramidoid, it's more complicate for Spheroid. Then we

will consider for the Spheroid the bounding box of the equivalent Facoid $\left(\vec{P} - \sum_{i \in I} (0.5 * \vec{A}_i), \{\vec{A}_i\}_{i \in I}\right)$ which gives the smallest bounding box when axis of the Spheroid are colinear to axis of the standard coordinate system and a bounding box slightly too large when not colinear.

The bounding box is defined as follow, for a Facoid:

$$\left(\vec{P}', \{\vec{A}_i'\}_{i \in I}\right) \quad (14)$$

where

$$\begin{cases} P'_i = P_i + \sum_{j \in I^-} A_{ji} \\ A'_{ij} = 0.0, i \neq j \\ A'_{ij} = \sum_{k \in I^+} A_{kj} - \sum_{k \in I^-} A_{kj}, i = j \end{cases} \quad (15)$$

and, I^+ and I^- are the subsets of I such as $\forall j \in I^+, A_{ij} \geq 0.0$ and $\forall j \in I^-, A_{ij} < 0.0$.

for a Pyramidoid:

$$\left(\vec{P}', \{\vec{A}_i'\}_{i \in I}\right) \quad (16)$$

where

$$\begin{cases} P'_i = P_i + \text{Min}(\text{Min}_{j \in I}(A_{ji}), 0.0) \\ A'_{ij} = 0.0, i \neq j \\ A'_{ij} = \text{Max}_{k \in I}(A_{kj}) - \text{Min}_{k \in I}(A_{kj}), i = j \end{cases} \quad (17)$$

1.5 Depth and Center

Depth $\mathbf{D}_S(\vec{X})$ of position \vec{X} a Shapoid S is a value ranging from 0.0 if \vec{X} is on the surface of the Shapoid, to 1.0 if \vec{X} is at the farthest location from the surface inside the Shapoid. Depth is by definition equal to 0.0 if \vec{X} is outside the Shapoid. Depth is continuous and derivable on the volume of the Shapoid. It is defined by, for a Facoid:

$$\mathbf{D}_S(\vec{X}) = \prod_{i \in I} (1.0 - 4.0 * (0.5 - X_i^S)^2) \quad (18)$$

for a Pyramidoid:

$$\mathbf{D}_S(\vec{X}) = \prod_{i \in I} \left(1.0 - 4.0 * \left(0.5 - \frac{X_i^S}{1.0 - \sum_{j \in I - \{i\}} X_j^S} \right)^2 \right) \quad (19)$$

and for a Spheroid:

$$\mathbf{D}_S(\vec{X}) = 1.0 - 2.0 * \left\| \vec{X}^S \right\| \quad (20)$$

The maximum depth is obtained at \vec{C} such as, for a Facoid:

$$\forall i \in I, C_i^S = 0.5 \quad (21)$$

for a Pyramidoid:

$$\forall i \in I, C_i^S = \frac{1}{D+1} \quad (22)$$

for a Spheroid:

$$\forall i \in I, C_i^S = 0.0 \quad (23)$$

\vec{C} is called the center of the Shapoid.

1.6 Iterator on Spheroid

While a sequential path through a Facoid and a Pyramidoid is obvious, path through a Spheroid is more complex. The solution implemented is described below.

Given a Spheroid of dimension N we start from an arbitrary position: $< 0, 0, \dots, -0.5 >$. From there we step the axis starting from the first one. If we could step an axis the step algorithm stops and return the new position as it could successfully step. However, if we could step on an axis other than the first one, it means we have modified the constraint for previous axis, the constraint being "is inside the spheroid". Then we reposition the axis before the stepped one to its lower possible value. It will allow it to step again at the next iteration on a new boundary defined by other axis values, and this scale up naturally to any dimension. Care must be care to the case when an axis reaches its upper value: the delta given by the user and the influence of other axis value make it jumps "over" the boundary in most cases. To keep things neat and clean we recalculate the exact value of the axis for its last step instead of using the delta given by the user.

The calculation of the lower and upper values of an axis given the values of other axis can be performed as follow:

Lets note $\vec{P} = \langle p_0, p_1, \dots, p_{N-1} \rangle$ the position in a Spheroid of dimension N . A position will be on the boundary of the Spheroid if and only if $\|\vec{P}\| = 0.5$. We want to calculate α which bring a position \vec{P}' inside the Spheroid to a position \vec{P} on the boundary of the Spheroid by modifying the axis i (i.e. $p_i = p'_i + \alpha$ and $p_j = p'_j, j \neq i$). Lets note $n = \|\vec{P}'\|$. We have:

$$p_0'^2 + p_1'^2 + \dots + p_i'^2 + \dots + p_{N-1}'^2 = n^2 \quad (24)$$

and

$$p_0^2 + p_1^2 + \dots + p_i^2 + \dots + p_{N-1}^2 = 0.25 \quad (25)$$

equivalent to

$$p_0'^2 + p_1'^2 + \dots + (p'_i + \alpha)^2 + \dots + p_{N-1}'^2 = 0.25 \quad (26)$$

by substracting (24) and (26) we have

$$p_i'^2 - (p'_i + \alpha)^2 = n^2 - 0.25 \quad (27)$$

equivalent to

$$p_i'^2 - (p_i'^2 + \alpha^2 + 2p'_i\alpha) = n^2 - 0.25 \quad (28)$$

equivalent to

$$-\alpha^2 - 2p'_i\alpha - (n^2 - 0.25) = 0 \quad (29)$$

simplified to

$$\alpha^2 + 2p'_i\alpha + (n^2 - 0.25) = 0 \quad (30)$$

This quadratic equation can be solved directly to obtain α :

$$\alpha = \frac{-2p'_i \pm \sqrt{4p_i'^2 - 4(n^2 - 0.25)}}{2} \quad (31)$$

Which gives the two solutions defining the lower and upper boundaries of the Spheroid on the axis i .

This result can then be used to solve our problem with what I'll call the "Wormy Algorithm":

```

flag := true
norm := Norm(P)
iDim := 0
loop until (iDim < N and flag == true)
    prevNorm := norm
    P_iDim := P_iDim + delta
    norm := Norm(P)
    if (prevNorm < 0.5 and norm > 0.5)
        P_iDim := 0
        norm := Norm(P)
        val := 0.5 * Sqrt(-4.0 * (norm^2 - 0.25))
        P_iDim := val
        norm := 0.5
        flag := false
        iDim := iDim - 1
    else
        if (norm > 0.5)
            P_iDim := 0
        else
            flag := false
            iDim := iDim - 1
        end if
    end if
    iDim := iDim + 1
end loop
if (flag == false)
    iDim := iDim - 1
    if (iDim >= 0)
        P_iDim := P_iDim + 0.5 * (-2.0 * P_iDim -
            Sqrt(4.0 * (P_iDim)^2 - 4.0 * (norm^2 - 0.25)))
    end if
end if
return Not(flag)

```

This algorithm step P to the next position in the path by δ and returns true if we haven't reached the end of the path, or false if we have reached the end of the path (i.e. if we have iterated through all the surface/volume/... of the Spheroid). Remember that P must be initialised to $\langle 0, 0, \dots, -0.5 \rangle$ as the beginning of the path, and that **ShapoidIter** iterates coordinates in the Shapoid's coordinate system.

2 Interface

```

// ===== SHAPOID.H =====

#ifndef SHAPOID_H
#define SHAPOID_H

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

#include <stdlib.h>
#include <stdio.h>
#include <math.h>

```

```

#include <string.h>
#include <stdbool.h>
#include "pberr.h"
#include "pbmath.h"
#include "gset.h"

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

#define CloneShapoidType typedef struct {Shapoid _s;}

#define SpheroidCreate(Dim) \
    (Spheroid*)ShapoidCreate(Dim, ShapoidTypeSpheroid)
#define FacoidCreate(Dim) \
    (Facoid*)ShapoidCreate(Dim, ShapoidTypeFacoid)
#define PyramidoidCreate(Dim) \
    (Pyramidoid*)ShapoidCreate(Dim, ShapoidTypePyramidoid)

#define ShapoidGetCoverage(ShapoidA, ShapoidB) \
    _ShapoidGetCoverageDelta((Shapoid*)ShapoidA, (Shapoid*)ShapoidB, 0.1)
#define ShapoidGetCoverageDelta(ShapoidA, ShapoidB, Prec) \
    _ShapoidGetCoverageDelta((Shapoid*)ShapoidA, (Shapoid*)ShapoidB, Prec)

#define ShapoidIterCreateStatic(Shap, Delta) \
    _ShapoidIterCreateStatic((Shapoid*)(Shap), (VecFloat*)(Delta))

#define ShapoidIterSetShapoid(Iter, Shap) \
    _ShapoidIterSetShapoid(Iter, (Shapoid*)(Shap))

#define ShapoidIterSetDelta(Iter, Delta) \
    _ShapoidIterSetDelta(Iter, (VecFloat*)(Delta))

extern const char* ShapoidTypeString[3];

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

#define ShapoidClone(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidClone, \
    Facoid*: FacoidClone, \
    Pyramidoid*: PyramidoidClone, \
    Spheroid*: SpheroidClone, \
    default: PBErrInvalidPolymorphism)(Shap)

#define ShapoidFree(ShapRef) _Generic(ShapRef, \
    Shapoid**: _ShapoidFree, \
    Facoid**: _ShapoidFree, \
    Pyramidoid**: _ShapoidFree, \
    Spheroid**: _ShapoidFree, \
    default: PBErrInvalidPolymorphism)((Shapoid**)(ShapRef))

#define ShapoidLoad(ShapRef, Stream) _Generic(ShapRef, \
    Shapoid**: _ShapoidLoad, \
    Facoid**: FacoidLoad, \
    Pyramidoid**: PyramidoidLoad, \
    Spheroid**: SpheroidLoad, \
    default: PBErrInvalidPolymorphism)(ShapRef, Stream)

#define ShapoidSave(Shap, Stream) _Generic(Shap, \
    Shapoid*: _ShapoidSave, \
    Facoid*: _ShapoidSave, \
    Pyramidoid*: _ShapoidSave, \
    Spheroid*: _ShapoidSave, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Stream)

```



```

#define ShapoidPrintln(Shap, Stream) _Generic(Shap, \
    Shapoid*: _ShapoidPrintln, \
    Facoid*: _ShapoidPrintln, \
    Pyramidoid*: _ShapoidPrintln, \
    Spheroid*: _ShapoidPrintln, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Stream)

#define ShapoidGetType(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidGetType, \
    Facoid*: _ShapoidGetType, \
    Pyramidoid*: _ShapoidGetType, \
    Spheroid*: _ShapoidGetType, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap))

#define ShapoidGetTypeAsString(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidGetTypeAsString, \
    Facoid*: _ShapoidGetTypeAsString, \
    Pyramidoid*: _ShapoidGetTypeAsString, \
    Spheroid*: _ShapoidGetTypeAsString, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap))

#define ShapoidGetDim(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidGetDim, \
    Facoid*: _ShapoidGetDim, \
    Pyramidoid*: _ShapoidGetDim, \
    Spheroid*: _ShapoidGetDim, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap))

#define ShapoidGetPos(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidGetPos, \
    Facoid*: _ShapoidGetPos, \
    Pyramidoid*: _ShapoidGetPos, \
    Spheroid*: _ShapoidGetPos, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap))

#define ShapoidPos(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidPos, \
    Facoid*: _ShapoidPos, \
    Pyramidoid*: _ShapoidPos, \
    Spheroid*: _ShapoidPos, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap))

#define ShapoidSetAxis(Shap, Index, Vec) _Generic(Shap, \
    Shapoid*: _ShapoidSetAxis, \
    Facoid*: _ShapoidSetAxis, \
    Pyramidoid*: _ShapoidSetAxis, \
    Spheroid*: _ShapoidSetAxis, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Index, \
    (VecFloat*)Vec)

#define ShapoidSetPos(Shap, Vec) _Generic(Shap, \
    Shapoid*: _ShapoidSetPos, \
    Facoid*: _ShapoidSetPos, \
    Pyramidoid*: _ShapoidSetPos, \
    Spheroid*: _ShapoidSetPos, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), (VecFloat*)Vec)

#define ShapoidGetAxis(Shap, Index) _Generic(Shap, \
    Shapoid*: _ShapoidGetAxis, \
    Facoid*: _ShapoidGetAxis, \
    Pyramidoid*: _ShapoidGetAxis, \

```

```

    Spheroid*: _ShapoidGetAxis, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Index)

#define ShapoidAxis(Shap, Index) _Generic(Shap, \
    Shapoid*: _ShapoidAxis, \
    Facoid*: _ShapoidAxis, \
    Pyramidoid*: _ShapoidAxis, \
    Spheroid*: _ShapoidAxis, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Index)

#define ShapoidTranslate(Shap, Vec) _Generic(Shap, \
    Shapoid*: _ShapoidTranslate, \
    Facoid*: _ShapoidTranslate, \
    Pyramidoid*: _ShapoidTranslate, \
    Spheroid*: _ShapoidTranslate, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), (VecFloat*)Vec)

#define ShapoidIsEqual(ShapA, ShapB) _Generic(ShapA, \
    Shapoid*: _ShapoidIsEqual, \
    Facoid*: _ShapoidIsEqual, \
    Pyramidoid*: _ShapoidIsEqual, \
    Spheroid*: _ShapoidIsEqual, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(ShapA), \
    (Shapoid*)(ShapB))

#define ShapoidGetBoundingBox(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidGetBoundingBox, \
    Facoid*: FacoidGetBoundingBox, \
    Pyramidoid*: PyramidoidGetBoundingBox, \
    Spheroid*: SpheroidGetBoundingBox, \
    GSet*: ShapoidGetBoundingBoxSet, \
    default: PBErrInvalidPolymorphism)(Shap)

#define ShapoidScale(Shap, Scale) _Generic(Scale, \
    VecFloat*: _ShapoidScaleVector, \
    VecFloat2D*: _ShapoidScaleVector, \
    VecFloat3D*: _ShapoidScaleVector, \
    float: _ShapoidScaleScalar, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Scale)

#define ShapoidGrow(Shap, Scale) _Generic(Shap, \
    Shapoid*: _Generic(Scale, \
        VecFloat*: _ShapoidGrowVector, \
        float: _ShapoidGrowScalar, \
        default: PBErrInvalidPolymorphism), \
    Facoid*: _Generic(Scale, \
        VecFloat*: _ShapoidGrowVector, \
        float: _ShapoidGrowScalar, \
        default: PBErrInvalidPolymorphism), \
    Pyramidoid*: _Generic(Scale, \
        VecFloat*: _ShapoidGrowVector, \
        float: _ShapoidGrowScalar, \
        default: PBErrInvalidPolymorphism), \
    Spheroid*: _Generic(Scale, \
        VecFloat*: _ShapoidGrowVector, \
        float: _ShapoidGrowScalar, \
        default: PBErrInvalidPolymorphism), \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Scale)

#define ShapoidGetCenter(Shap) _Generic(Shap, \
    Shapoid*: _ShapoidGetCenter, \
    Facoid*: FacoidGetCenter, \

```

```

Pyramidoid*: PyramidoidGetCenter, \
Spheroid*: SpheroidGetCenter, \
default: PBErrInvalidPolymorphism)(Shap)

#define ShapoidRotCenter(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotCenter, \
    Facoid*: _ShapoidRotCenter, \
    Pyramidoid*: _ShapoidRotCenter, \
    Spheroid*: _ShapoidRotCenter, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotOrigin(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotOrigin, \
    Facoid*: _ShapoidRotOrigin, \
    Pyramidoid*: _ShapoidRotOrigin, \
    Spheroid*: _ShapoidRotOrigin, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotStart(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotStart, \
    Facoid*: _ShapoidRotStart, \
    Pyramidoid*: _ShapoidRotStart, \
    Spheroid*: _ShapoidRotStart, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotAxisCenter(Shap, Axis, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotAxisCenter, \
    Facoid*: _ShapoidRotAxisCenter, \
    Pyramidoid*: _ShapoidRotAxisCenter, \
    Spheroid*: _ShapoidRotAxisCenter, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Axis, Theta)

#define ShapoidRotAxisOrigin(Shap, Axis, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotAxisOrigin, \
    Facoid*: _ShapoidRotAxisOrigin, \
    Pyramidoid*: _ShapoidRotAxisOrigin, \
    Spheroid*: _ShapoidRotAxisOrigin, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Axis, Theta)

#define ShapoidRotAxisStart(Shap, Axis, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotAxisStart, \
    Facoid*: _ShapoidRotAxisStart, \
    Pyramidoid*: _ShapoidRotAxisStart, \
    Spheroid*: _ShapoidRotAxisStart, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Axis, Theta)

#define ShapoidRotXCenter(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotXCenter, \
    Facoid*: _ShapoidRotXCenter, \
    Pyramidoid*: _ShapoidRotXCenter, \
    Spheroid*: _ShapoidRotXCenter, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotXOrigin(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotXOrigin, \
    Facoid*: _ShapoidRotXOrigin, \
    Pyramidoid*: _ShapoidRotXOrigin, \
    Spheroid*: _ShapoidRotXOrigin, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotXStart(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotXStart, \

```

```

    Facoid*: _ShapoidRotXStart, \
    Pyramidoid*: _ShapoidRotXStart, \
    Spheroid*: _ShapoidRotXStart, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotYCenter(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotYCenter, \
    Facoid*: _ShapoidRotYCenter, \
    Pyramidoid*: _ShapoidRotYCenter, \
    Spheroid*: _ShapoidRotYCenter, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotYOrigin(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotYOrigin, \
    Facoid*: _ShapoidRotYOrigin, \
    Pyramidoid*: _ShapoidRotYOrigin, \
    Spheroid*: _ShapoidRotYOrigin, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotYStart(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotYStart, \
    Facoid*: _ShapoidRotYStart, \
    Pyramidoid*: _ShapoidRotYStart, \
    Spheroid*: _ShapoidRotYStart, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotZCenter(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotZCenter, \
    Facoid*: _ShapoidRotZCenter, \
    Pyramidoid*: _ShapoidRotZCenter, \
    Spheroid*: _ShapoidRotZCenter, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotZOrigin(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotZOrigin, \
    Facoid*: _ShapoidRotZOrigin, \
    Pyramidoid*: _ShapoidRotZOrigin, \
    Spheroid*: _ShapoidRotZOrigin, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidRotZStart(Shap, Theta) _Generic(Shap, \
    Shapoid*: _ShapoidRotZStart, \
    Facoid*: _ShapoidRotZStart, \
    Pyramidoid*: _ShapoidRotZStart, \
    Spheroid*: _ShapoidRotZStart, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), Theta)

#define ShapoidImportCoord(Shap, VecPos) _Generic(Shap, \
    Shapoid*: _ShapoidImportCoord, \
    Facoid*: _ShapoidImportCoord, \
    Pyramidoid*: _ShapoidImportCoord, \
    Spheroid*: _ShapoidImportCoord, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), \
    (VecFloat*)VecPos)

#define ShapoidExportCoord(Shap, VecPos) _Generic(Shap, \
    Shapoid*: _ShapoidExportCoord, \
    Facoid*: _ShapoidExportCoord, \
    Pyramidoid*: _ShapoidExportCoord, \
    Spheroid*: _ShapoidExportCoord, \
    default: PBErrInvalidPolymorphism)((Shapoid*)(Shap), \
    (VecFloat*)VecPos)

```

```

#define ShapoidIsPosInside(Shap, VecPos) _Generic(Shap, \
    Shapoid*: _ShapoidIsPosInside, \
    Facoid*: FacoidIsPosInside, \
    Pyramidoid*: PyramidoidIsPosInside, \
    Spheroid*: SpheroidIsPosInside, \
    default: PBErrInvalidPolymorphism)(Shap, VecPos)

#define ShapoidGetPosDepth(Shap, VecPos) _Generic(Shap, \
    Shapoid*: _ShapoidGetPosDepth, \
    Facoid*: FacoidGetPosDepth, \
    Pyramidoid*: PyramidoidGetPosDepth, \
    Spheroid*: SpheroidGetPosDepth, \
    default: PBErrInvalidPolymorphism)(Shap, (VecFloat*)VecPos)

// ----- ShapoidIter

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

typedef enum ShapoidType {
    ShapoidTypeFacoid, ShapoidTypeSpheroid,
    ShapoidTypePyramidoid
} ShapoidType;
// Don't forget to update ShapoidTypeString in shapoid.c when adding
// new type

typedef struct Shapoid {
    // Position of origin
    VecFloat* _pos;
    // Dimension
    int _dim;
    // Vectors defining axes
    VecFloat** _axis;
    // Type of Shapoid
    ShapoidType _type;
    // Linear sytem used to import coordinates
    SysLinEq* _sysLinEqImport;
} Shapoid;

CloneShapoidType Facoid;
CloneShapoidType Pyramidoid;
CloneShapoidType Spheroid;

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

// Create a Shapoid of dimension 'dim' and type 'type', default values:
// _pos = null vector
// _axis[d] = unit vector along dimension d
Shapoid* ShapoidCreate(int dim, ShapoidType type);

// Clone a Shapoid
Shapoid* _ShapoidClone(Shapoid* that);
inline Facoid* FacoidClone(Facoid* that) {
    return (Facoid*)_ShapoidClone((Shapoid*)that);
}
inline Pyramidoid* PyramidoidClone(Pyramidoid* that) {
    return (Pyramidoid*)_ShapoidClone((Shapoid*)that);
}
inline Spheroid* SpheroidClone(Spheroid* that) {
    return (Spheroid*)_ShapoidClone((Shapoid*)that);
}

```

```

// Free memory used by a Shapoid
void _ShapoidFree(Shapoid** that);

// Load the Shapoid of type 'type' from the stream
// If the Shapoid is already allocated, it is freed before loading
// Return true upon success else false
bool _ShapoidLoad(Shapoid** that, FILE* stream, ShapoidType type);
inline bool FacoidLoad(Facoid** that, FILE* stream) {
    return _ShapoidLoad((Shapoid**)that, stream, ShapoidTypeFacoid);
}
inline bool PyramidoidLoad(Pyramidoid** that, FILE* stream) {
    return _ShapoidLoad((Shapoid**)that, stream,
        ShapoidTypePyramidoid);
}
inline bool SpheroidLoad(Spheroid** that, FILE* stream) {
    return _ShapoidLoad((Shapoid**)that, stream,
        ShapoidTypeSpheroid);
}

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

// Print the Shapoid on 'stream'
void _ShapoidPrintln(Shapoid* that, FILE* stream);

// Get the dimension of the Shapoid
#ifdef BUILDMODE != 0
inline
#endif
int _ShapoidGetDim(Shapoid* that);

// Get the type of the Shapoid
#ifdef BUILDMODE != 0
inline
#endif
ShapoidType _ShapoidGetType(Shapoid* that);

// Get the type of the Shapoid as a string
// Return a pointer to a constant string (not to be freed)
#ifdef BUILDMODE != 0
inline
#endif
const char* _ShapoidGetTypeAsString(Shapoid* that);

// Return a VecFloat equals to the position of the Shapoid
#ifdef BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidGetPos(Shapoid* that);

// Return a VecFloat equals to the 'dim'-th axis of the Shapoid
#ifdef BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidGetAxis(Shapoid* that, int dim);

// Return the position of the Shapoid
#ifdef BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidPos(Shapoid* that);

```

```

// Return the 'dim'-th axis of the Shapoid
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidAxis(Shapoid* that, int dim);

// Set the position of the Shapoid to 'pos'
#if BUILDMODE != 0
inline
#endif
void _ShapoidSetPos(Shapoid* that, VecFloat* pos);

// Set the 'dim'-th axis of the Shapoid to 'v'
#if BUILDMODE != 0
inline
#endif
void _ShapoidSetAxis(Shapoid* that, int dim, VecFloat* v);

// Translate the Shapoid by 'v'
#if BUILDMODE != 0
inline
#endif
void _ShapoidTranslate(Shapoid* that, VecFloat* v);

// Scale the Shapoid by 'v' (each axis is multiplied by v[iAxis])
#if BUILDMODE != 0
inline
#endif
void _ShapoidScaleVector(Shapoid* that, VecFloat* v);

// Scale the Shapoid by 'c'
#if BUILDMODE != 0
inline
#endif
void _ShapoidScaleScalar(Shapoid* that, float c);

// Scale the Shapoid by 'v' (each axis is multiplied by v[iAxis])
// and translate the Shapoid such as its center after scaling
// is at the same position than before scaling
#if BUILDMODE != 0
inline
#endif
void _ShapoidGrowVector(Shapoid* that, VecFloat* v);

// Scale the Shapoid by 'c'
// and translate the Shapoid such as its center after scaling
// is at the same position than before scaling
#if BUILDMODE != 0
inline
#endif
void _ShapoidGrowScalar(Shapoid* that, float c);

// Rotate the Shapoid of dimension 2 by 'theta' (in radians, CCW)
// relatively to its center
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotCenter(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 2 by 'theta' (in radians, CCW)
// relatively to its position

```

```

#if BUILDMODE != 0
inline
#endif
void _ShapoidRotStart(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 2 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotOrigin(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its center around 'axis'
// 'axis' must be normalized
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotAxisCenter(Shapoid* that, VecFloat3D* axis,
    float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around 'axis'
// 'axis' must be normalized
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotAxisStart(Shapoid* that, VecFloat3D* axis, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around 'axis'
// 'axis' must be normalized
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotAxisOrigin(Shapoid* that, VecFloat3D* axis,
    float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its center around X
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotXCenter(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around X
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotXStart(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around X
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotXOrigin(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)

```



```

// relatively to its center around Y
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotYCenter(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around Y
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotYStart(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around Y
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotYOrigin(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its center around Z
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotZCenter(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around Z
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotZStart(Shapoid* that, float theta);

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around Z
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotZOrigin(Shapoid* that, float theta);

// Convert the coordinates of 'pos' from standard coordinate system
// toward the Shapoid coordinates system
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidImportCoord(Shapoid* that, VecFloat* pos);

// Convert the coordinates of 'pos' from the Shapoid coordinates system
// toward standard coordinate system
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidExportCoord(Shapoid* that, VecFloat* pos);

// Return true if 'pos' (in standard coordinates system) is inside the
// Shapoid
// Else return false
#if BUILDMODE != 0
inline

```

```

#endif
bool _ShapoidIsPosInside(Shapoid* that, VecFloat* pos);
#if BUILDMODE != 0
inline
#endif
bool FacoidIsPosInside(Facoid* that, VecFloat* pos);
#if BUILDMODE != 0
inline
#endif
bool PyramidoidIsPosInside(Pyramidoid* that, VecFloat* pos);
#if BUILDMODE != 0
inline
#endif
bool SpheroidIsPosInside(Spheroid* that, VecFloat* pos);

// Get a bounding box of the Shapoid. The bounding box is aligned
// on the standard coordinate system (its axis are colinear with
// the axis of the standard coordinate system).
// The bounding box is returned as a Facoid, which position is
// at the minimum value along each axis.
Facoid* _ShapoidGetBoundingBox(Shapoid* that);
Facoid* FacoidGetBoundingBox(Facoid* that);
Facoid* PyramidoidGetBoundingBox(Pyramidoid* that);
Facoid* SpheroidGetBoundingBox(Spheroid* that);

// Get the bounding box of a set of Facoid. The bounding box is aligned
// on the standard coordinate system (its axis are colinear with
// the axis of the standard coordinate system).
// The bounding box is returned as a Facoid, which position is
// at the minimum value along each axis.
Facoid* ShapoidGetBoundingBoxSet(GSet* set);

// Get the depth value in the Shapoid of 'pos' in standard coordinate
// system
// The depth is defined as follow: the point with depth equals 1.0 is
// the farthest point from the surface of the Shapoid (inside it),
// points with depth equals to 0.0 are point on the surface of the
// Shapoid. Depth is continuous and derivable over the volume of the
// Shapoid
// Return 0.0 if pos is outside the Shapoid
#if BUILDMODE != 0
inline
#endif
float _ShapoidGetPosDepth(Shapoid* that, VecFloat* pos);
#if BUILDMODE != 0
inline
#endif
float FacoidGetPosDepth(Facoid* that, VecFloat* pos);
#if BUILDMODE != 0
inline
#endif
float PyramidoidGetPosDepth(Pyramidoid* that, VecFloat* pos);
#if BUILDMODE != 0
inline
#endif
float SpheroidGetPosDepth(Spheroid* that, VecFloat* pos);

// Get the center of the shapoid in standard coordinate system
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidGetCenter(Shapoid* that);

```

```

#if BUILDMODE != 0
inline
#endif
VecFloat* FacoidGetCenter(Facoid* that);
#if BUILDMODE != 0
inline
#endif
VecFloat* PyramidoidGetCenter(Pyramidoid* that);
#if BUILDMODE != 0
inline
#endif
VecFloat* SpheroidGetCenter(Spheroid* that);

// Get the percentage of 'tho' included into 'that' (in [0.0, 1.0])
// 0.0 -> 'tho' is completely outside of 'that'
// 1.0 -> 'tho' is completely inside of 'that'
// 'that' and 'tho' must me of same dimensions
// delta is the step of the algorithm (in ]0.0, 1.0])
// small -> slow but precise
// big -> fast but rough
float _ShapoidGetCoverageDelta(Shapoid* that, Shapoid* tho, float delta);

// Update the system of linear equation used to import coordinates
#if BUILDMODE != 0
inline
#endif
void ShapoidUpdateSysLinEqImport(Shapoid* that);

// Check if shapoid 'that' and 'tho' are equals
#if BUILDMODE != 0
inline
#endif
bool _ShapoidIsEqual(Shapoid* that, Shapoid* tho);

// Add a copy of the Facoid 'that' to the GSet 'set' (containing
// other Facoid), taking care to avoid overlapping Facoid
// The copy of 'that' made be resized or divided
// The Facoid in the set and 'that' must be aligned with the
// coordinates system axis and have
// same dimensions
void FacoidAlignedAddClippedToSet(Facoid* that, GSet* set);

// Check if the Facoid 'that' is completely included into the Facoid
// 'facoid'
// Both Facoid must be aligned with the coordinates system and have
// same dimensions
// Return true if it is included, false else
bool FacoidAlignedIsInsideFacoidAligned(Facoid* that, Facoid* facoid);

// Check if the Facoid 'that' is completely excluded from the Facoid
// 'facoid'
// Both Facoid must be aligned with the coordinates system and have
// same dimensions
// Return true if it is excluded, false else
bool FacoidAlignedIsOutsideFacoidAligned(Facoid* that, Facoid* facoid);

// Get a GSet of Facoid aligned with coordinates system covering the
// Facoid 'that' except for area in the Facoid 'facoid'
// Both Facoid must be aligned with the coordinates system and have
// same dimensions
GSet* FacoidAlignedSplitExcludingFacoidAligned(Facoid* that,
    Facoid* facoid);

```

```

// ----- ShapoidIter

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

typedef struct ShapoidIter {
    // Attached shapoid
    Shapoid* _shap;
    // Delta step
    VecFloat* _delta;
    // Current position (in internal coordinates of the shapoid)
    VecFloat* _pos;
} ShapoidIter;

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

// Create a new iterator on the Shapoid 'shap' with a step of 'delta'
// (step on the internal coordinates of the Shapoid)
// The iterator is initialized and ready to be stepped
ShapoidIter _ShapoidIterCreateStatic(Shapoid* shap, VecFloat* delta);

// Free the memory used by the ShapoidIter 'that'
void ShapoidIterFreeStatic(ShapoidIter* that);

// Reinitialise the ShapoidIter 'that' to its starting position
void ShapoidIterInit(ShapoidIter* that);

// Step the ShapoidIter 'that'
// Return false if the iterator is at its end and couldn't be stepped
bool ShapoidIterStep(ShapoidIter* that);

// Return the current position in Shapoid coordinates of the
// ShapoidIter 'that'
#ifdef BUILDMODE != 0
inline
#endif
VecFloat* ShapoidIterGetInternal(ShapoidIter* that);

// Return the current position in standard coordinates of the
// ShapoidIter 'that'
#ifdef BUILDMODE != 0
inline
#endif
VecFloat* ShapoidIterGetExternal(ShapoidIter* that);

// Set the attached Shapoid of the ShapoidIter 'that' to 'shap'
// The iterator is reset to its initial position
#ifdef BUILDMODE != 0
inline
#endif
void _ShapoidIterSetShapoid(ShapoidIter* that, Shapoid* shap);

// Get the Shapoid of the ShapoidIter 'that'
#ifdef BUILDMODE != 0
inline
#endif
Shapoid* ShapoidIterShapoid(ShapoidIter* that);

// Set the delta of the ShapoidIter 'that' to a copy of 'delta'
#ifdef BUILDMODE != 0
inline
#endif

```

```

void _ShapoidIterSetDelta(ShapoidIter* that, VecFloat* delta);

// Get the delta of the ShapoidIter 'that'
#if BUILDMODE != 0
inline
#endif
VecFloat* ShapoidIterDelta(ShapoidIter* that);

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

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

#endif

```

3 Code

3.1 shapoid.c

```

// ===== SHAPOID.C =====

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

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

// ----- Shapoid

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

const char* ShapoidTypeString[3] = {
    (const char*)"Facoid", (const char*)"Spheroid",
    (const char*)"Pyramidoid"};

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

// Create a Shapoid of dimension 'dim' and type 'type', default values:
// _pos = null vector
// _axis[d] = unit vector along dimension d
Shapoid* ShapoidCreate(int dim, ShapoidType type) {
    #if BUILDMODE == 0
        if (dim <= 0) {
            ShapoidErr->_type = PBErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg, "Invalid dimension (%d>0)", dim);
            PBErrCatch(ShapoidErr);
        }
    #endif
    // Declare a vector used for initialisation
    VecShort2D d = VecShortCreateStatic2D();
    // Declare a identity matrix used for initialisation
    VecSet(&d, 0, dim);
    VecSet(&d, 1, dim);
}

```

```

MatFloat* mat = MatFloatCreate(&d);
MatSetIdentity(mat);
// Allocate memory
Shapoid* that = PBErrMalloc(ShapoidErr, sizeof(Shapoid));
// Init pointers
that->_pos = NULL;
that->_axis = NULL;
that->_sysLinEqImport = NULL;
// Set the dimension and type
that->_type = type;
that->_dim = dim;
// Allocate memory for position
that->_pos = VecFloatCreate(dim);
// Allocate memory for array of axis
that->_axis = PBErrMalloc(ShapoidErr, sizeof(VecFloat*) * dim);
for (int iAxis = dim; iAxis--;)
    that->_axis[iAxis] = NULL;
// Allocate memory for each axis
for (int iAxis = 0; iAxis < dim; ++iAxis) {
    // Allocate memory for position
    that->_axis[iAxis] = VecFloatCreate(dim);
    // Set value of the axis
    VecSet(that->_axis[iAxis], iAxis, 1.0);
}
// Create the linear system for coordinate importation
that->_sysLinEqImport = SysLinEqCreate(mat, (VecFloat*)NULL);
// Free memory
MatFree(&mat);
// Return the new Shapoid
return that;
}

// Clone a Shapoid
Shapoid* _ShapoidClone(Shapoid* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Create a clone
    Shapoid* clone = ShapoidCreate(that->_dim, that->_type);
    // Set the position and axis of the clone
    ShapoidSetPos(clone, that->_pos);
    for (int iAxis = clone->_dim; iAxis--;)
        VecCopy(clone->_axis[iAxis], that->_axis[iAxis]);
    ShapoidUpdateSysLinEqImport(clone);
    // Clone the SysLinEq
    SysLinEqFree(&(clone->_sysLinEqImport));
    clone->_sysLinEqImport = SysLinEqClone(that->_sysLinEqImport);
    // Return the clone
    return clone;
}

// Free memory used by a Shapoid
void _ShapoidFree(Shapoid** that) {
    // Check argument
    if (that == NULL || *that == NULL)
        return;
    // Free memory
    for (int iAxis = (*that)->_dim; iAxis--;)

```

```

    VecFree((*that)->_axis + iAxis);
    free((*that)->_axis);
    VecFree(&((*that)->_pos));
    SysLinEqFree(&((*that)->_sysLinEqImport));
    free(*that);
    *that = NULL;
}

// Load the Shapoid from the stream
// If the Shapoid is already allocated, it is freed before loading
// Return true upon success else false
bool _ShapoidLoad(Shapoid** that, FILE* stream, ShapoidType type) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PErrCatch(ShapoidErr);
        }
        if (stream == NULL) {
            ShapoidErr->_type = PErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'stream' is null");
            PErrCatch(ShapoidErr);
        }
    #endif
    // If 'that' is already allocated
    if (*that != NULL)
        // Free memory
        ShapoidFree(that);
    // Read the dimension and type
    int dim;
    int ret = fscanf(stream, "%d", &dim);
    // If we couldn't fscanf
    if (ret == EOF)
        return false;
    if (dim <= 0)
        return false;
    ShapoidType typeLoad;
    ret = fscanf(stream, "%u", &typeLoad);
    // If we couldn't fscanf
    if (ret == EOF)
        return false;
    // Check the type
    if (type != typeLoad)
        return false;
    // Allocate memory
    *that = ShapoidCreate(dim, type);
    // Read the values
    bool ok = VecLoad(&((*that)->_pos), stream);
    if (ok == false)
        return false;
    for (int iAxis = 0; iAxis < dim; ++iAxis) {
        ok = VecLoad((*that)->_axis + iAxis, stream);
        if (ok == false)
            return false;
    }
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(*that);
    // Return success code
    return true;
}

// Save the Shapoid to the stream

```

```

// Return true upon success else false
bool _ShapoidSave(Shapoid* that, FILE* stream) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (stream == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'stream' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Save the dimension and type
    int ret = fprintf(stream, "%d %u\n", that->_dim, that->_type);
    // If we couldn't fprintf
    if (ret < 0)
        return false;
    // Save the position and axis
    bool ok = VecSave(that->_pos, stream);
    if (ok == false)
        return false;
    for (int iAxis = 0; iAxis < that->_dim; ++iAxis) {
        ok = VecSave(that->_axis[iAxis], stream);
        if (ok == false)
            return false;
    }
    // Return success code
    return true;
}

// Print the Shapoid on 'stream'
void _ShapoidPrintln(Shapoid* that, FILE* stream) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (stream == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'stream' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Print the Shapoid
    fprintf(stream, "Type: %s\n", ShapoidTypeString[that->_type]);
    fprintf(stream, "Dim: %d\n", that->_dim);
    fprintf(stream, "Pos: ");
    VecPrint(that->_pos, stream);
    fprintf(stream, "\n");
    for (int iAxis = 0; iAxis < that->_dim; ++iAxis) {
        fprintf(stream, "Axis(%d): ", iAxis);
        VecPrint(that->_axis[iAxis], stream);
        fprintf(stream, "\n");
    }
}

// Get a bounding box of the Shapoid. The bounding box is aligned
// on the standard coordinate system (its axis are colinear with
// the axis of the standard coordinate system).

```



```

// The bounding box is returned as a Facoid, which position is
// at the minimum value along each axis.
Facoid* _ShapoidGetBoundingBox(Shapoid* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PErrCatch(ShapoidErr);
    }
#endif
    // If the Shapoid is a Facoid
    if (that->_type == ShapoidTypeFacoid) {
        return FacoidGetBoundingBox((Facoid*)that);
    }
    // Else, if the Shapoid is a Pyramidoid
    } else if (that->_type == ShapoidTypePyramidoid) {
        return PyramidoidGetBoundingBox((Pyramidoid*)that);
    }
    // Else, if the Shapoid is a Spheroid
    } else if (that->_type == ShapoidTypeSpheroid) {
        return SpheroidGetBoundingBox((Spheroid*)that);
    }
    } else {
        return NULL;
    }
}

Facoid* FacoidGetBoundingBox(Facoid* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
#endif
    // Declare a variable to memorize the result
    Facoid* res = FacoidCreate(ShapoidGetDim(that));
    // For each axis
    for (int dim = ShapoidGetDim(that); dim--;) {
        // Declare a variable to memorize the bound of the interval on
        // this axis
        float bound[2];
        bound[0] = bound[1] = VecGet(((Shapoid*)that)->_pos, dim);
        // For each parameter
        for (int param = ShapoidGetDim(that); param--;) {
            // Get the value of the axis influencing the current dimension
            float v = VecGet(((Shapoid*)that)->_axis[param], dim);
            // If the value is negative, update the minimum bound
            if (v < 0.0)
                bound[0] += v;
            // Else, if the value is negative, update the minimum bound
            else
                bound[1] += v;
        }
        // Memorize the result
        VecSet(((Shapoid*)res)->_pos, dim, bound[0]);
        VecSet(((Shapoid*)res)->_axis[dim], dim, bound[1] - bound[0]);
    }
}

```

```

    // Return the result
    return res;
}

Facoid* PyramidoidGetBoundingBox(Pyramidoid* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Declare a variable to memorize the result
    Facoid* res = FacoidCreate(ShapoidGetDim(that));
    // For each axis
    for (int dim = ShapoidGetDim(that); dim--;) {
        // Declare a variable to memorize the bound of the interval on
        // this axis
        float bound[2];
        bound[0] = bound[1] = 0.0;
        // For each parameter
        for (int param = ShapoidGetDim(that); param--;) {
            // Get the value of the axis influencing the current dimension
            float v = VecGet(((Shapoid*)that)->_axis[param], dim);
            // Search the min and max values
            if (v < bound[0])
                bound[0] = v;
            if (v > bound[1])
                bound[1] = v;
        }
        if (bound[0] > 0.0)
            bound[0] = 0.0;
        if (bound[1] < 0.0)
            bound[1] = 0.0;
        // Memorize the result
        VecSet(((Shapoid*)res)->_pos, dim,
            VecGet(ShapoidPos(that), dim) + bound[0]);
        VecSet(((Shapoid*)res)->_axis[dim], dim, bound[1] - bound[0]);
    }
    // Return the result
    return res;
}

Facoid* SpheroidGetBoundingBox(Spheroid* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Declare a variable to memorize the result
    Facoid* res = FacoidCreate(ShapoidGetDim(that));
    // In case of a Spheroid, things get complicate
    // We'll approximate the bounding box of the Spheroid
    // with the one of the same Spheroid viewed as a Facoid
    // and simply take care that the _pos is at the center of the
    // Spheroid
    // For each axis
    for (int dim = ShapoidGetDim(that); dim--;) {
        // Declare a variable to memorize the bound of the interval on
        // this axis

```

```

float bound[2];
bound[0] = VecGet(((Shapoid*)that)->_pos, dim);
// Correct position
// For each parameter
for (int param = ShapoidGetDim(that); param--;) {
    // Get the value of the axis influencing the current dimension
    float v = VecGet(((Shapoid*)that)->_axis[param], dim);
    // Correct the pos
    bound[0] -= 0.5 * v;
}
bound[1] = bound[0];
// For each parameter
for (int param = ShapoidGetDim(that); param--;) {
    // Get the value of the axis influencing the current dimension
    float v = VecGet(((Shapoid*)that)->_axis[param], dim);
    // If the value is negative, update the minimum bound
    if (v < 0.0)
        bound[0] += v;
    // Else, if the value is negative, update the minimum bound
    else
        bound[1] += v;
}
// Memorize the result
VecSet(((Shapoid*)res)->_pos, dim, bound[0]);
VecSet(((Shapoid*)res)->_axis[dim], dim, bound[1] - bound[0]);
}
// Return the result
return res;
}

// Get the bounding box of a set of Facoid. The bounding box is aligned
// on the standard coordinate system (its axis are colinear with
// the axis of the standard coordinate system).
// The bounding box is returned as a Facoid, which position is
// at the minimum value along each axis.
Facoid* ShapoidGetBoundingBoxSet(GSet* set) {
#ifdef BUILDMODE == 0
    if (set == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'set' is null");
        PErrCatch(ShapoidErr);
    }
    GSetElem* elemCheck = set->_head;
    int dim = ((Shapoid*)(elemCheck->_data))->_dim;
    while (elemCheck != NULL) {
        if (((Shapoid*)(elemCheck->_data))->_dim != dim) {
            ShapoidErr->_type = PErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'set' contains Shapoids of various dimensions");
            PErrCatch(ShapoidErr);
        }
        elemCheck = elemCheck->_next;
    }
#endif
    // Declare a variable for the result
    Facoid* res = NULL;
    // Declare a pointer to the elements of the set
    GSetElem* elem = set->_head;
    // Loop on element of the set
    while (elem != NULL) {
        // Declare a pointer to the Facoid
        Shapoid* shapoid = (Shapoid*)(elem->_data);

```

```

// If it's the first Facoid in the set
if (res == NULL) {
    // Get the bounding box of this shapoid
    res = ShapoidGetBoundingBox(shapoid);
// Else, this is not the first Shapoid in the set
} else {
    // Get the bounding box of this shapoid
    Facoid* bound = ShapoidGetBoundingBox(shapoid);
    // For each dimension
    for (int iDim = ShapoidGetDim(res); iDim--;) {
        // Update the bounding box
        if (VecGet(((Shapoid*)bound)->_pos, iDim) <
            VecGet(((Shapoid*)res)->_pos, iDim)) {
            VecSet(((Shapoid*)res)->_axis[iDim], iDim,
                VecGet(((Shapoid*)res)->_axis[iDim], iDim) +
                VecGet(((Shapoid*)res)->_pos, iDim) -
                VecGet(((Shapoid*)bound)->_pos, iDim));
            VecSet(((Shapoid*)res)->_pos, iDim,
                VecGet(((Shapoid*)bound)->_pos, iDim));
        }
        if (VecGet(((Shapoid*)bound)->_pos, iDim) +
            VecGet(((Shapoid*)bound)->_axis[iDim], iDim) >
            VecGet(((Shapoid*)res)->_pos, iDim) +
            VecGet(((Shapoid*)res)->_axis[iDim], iDim))
            VecSet(((Shapoid*)res)->_axis[iDim], iDim,
                VecGet(((Shapoid*)bound)->_pos, iDim) +
                VecGet(((Shapoid*)bound)->_axis[iDim], iDim) -
                VecGet(((Shapoid*)res)->_pos, iDim));
    }
    // Free memory used by the bounding box
    ShapoidFree(&bound);
}
// Move to the next element
elem = elem->_next;
}
// Return the result
return res;
}

// Get the percentage of 'tho' included 'that' (in [0.0, 1.0])
// 0.0 -> 'tho' is completely outside of 'that'
// 1.0 -> 'tho' is completely inside of 'that'
// 'that' and 'tho' must me of same dimensions
// delta is the step of the algorithm (in ]0.0, 1.0])
// small -> slow but precise
// big -> fast but rough
float _ShapoidGetCoverageDelta(Shapoid* that, Shapoid* tho,
    float delta) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (tho == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'tho' is null");
        PBErrCatch(ShapoidErr);
    }
    if (ShapoidGetDim(that) != ShapoidGetDim(tho)) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,

```

```

        "Shapoids dimensions are different (%d==%d)",
        ShapoidGetDim(that), ShapoidGetDim(tho));
    PBErreCatch(ShapoidErr);
}
if (that->_type != ShapoidTypeFacoid &&
    that->_type != ShapoidTypeSpheroid &&
    that->_type != ShapoidTypePyramidoid) {
    ShapoidErr->_type = PBErreTypeInvalidArg;
    sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
    PBErreCatch(ShapoidErr);
}
#endif
// Declare variables to compute the result
float ratio = 0.0;
float sum = 0.0;
// Declare variables for the relative and absolute position in 'tho'
VecFloat* pRel = VecFloatCreate(ShapoidGetDim(that));
VecFloat* pStd = NULL;
// Declare a variable to memorize the last index in dimension
int lastI = VecGetDim(pRel) - 1;
// Declare a variable to memorize the max value of coordinates
float max = 1.0;
// If 'tho' is a spheroid, correct the start coordinates and range
if (tho->_type == ShapoidTypeSpheroid) {
    max = 0.5;
    for (int iDim = ShapoidGetDim(that); iDim--;)
        VecSet(pRel, iDim, -0.5);
}
// Loop on relative coordinates
while (VecGet(pRel, lastI) <= max + PBMath_EPSILON) {
    // Get the coordinates in standard system
    pStd = ShapoidExportCoord(tho, pRel);
    // If this position is inside 'tho'
    if (ShapoidIsPosInside(tho, pStd) == true) {
        // If this position is inside 'that'
        if (ShapoidIsPosInside(that, pStd) == true)
            // Increment the ratio
            ratio += 1.0;
        sum += 1.0;
    }
    // Free memory
    VecFree(&pStd);
    // Step the relative coordinates
    int iDim = 0;
    while (iDim >= 0) {
        VecSet(pRel, iDim, VecGet(pRel, iDim) + delta);
        if (iDim != lastI &&
            VecGet(pRel, iDim) > max + PBMath_EPSILON) {
            VecSet(pRel, iDim, max - 1.0);
            ++iDim;
        } else {
            iDim = -1;
        }
    }
}
// Finish the computation of the ratio
ratio /= sum;
// Free memory
VecFree(&pRel);
// Return the result
return ratio;
}

```

```

// Add a copy of the Facoid 'that' to the GSet 'set' (containing
// other Facoid), taking care to avoid overlapping Facoid
// The copy of 'that' made be resized or divided
// The Facoid in the set and 'that' must be aligned with the
// coordinates system axis and have
// same dimensions
void FacoidAlignedAddClippedToSet(Facoid* that, GSet* set) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (set == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'set' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // If the set is empty
    if (GSetNbElem(set) == 0) {
        // Add a clone of the facoid
        GSetAppend(set, FacoidClone(that));
    } else {
        // Create a set of sub facoid to be added and initialize it with a
        // clone of 'that'
        GSet setToAdd = GSetCreateStatic();
        GSetAppend(&setToAdd, FacoidClone(that));
        // For each sub facoid to add
        GSetIterForward iterToAdd = GSetIterForwardCreateStatic(&setToAdd);
        do {
            // Get the current facoid to add
            Facoid* facoidToAdd = GSetIterGet(&iterToAdd);
            // Declare a flag to skip the loop when possible
            bool flagSkip = false;
            // For each facoid in the set
            GSetIterForward iter = GSetIterForwardCreateStatic(set);
            do {
                // Get the current facoid
                Facoid* facoid = GSetIterGet(&iter);
                // If the facoid to be added is completely included into this
                // facoid
                if (FacoidAlignedIsInsideFacoidAligned(facoidToAdd, facoid)) {
                    // This facoid doesn't need to be added, delete it
                    ShapoidFree(&facoidToAdd);
                    GSetIterGetElem(&iterToAdd)->_data = NULL;
                    // And skip the other facoids in the set
                    flagSkip = true;
                } else if (this facoid is completely include in the facoid to
                // be added
                } else if (FacoidAlignedIsInsideFacoidAligned(facoid,
                facoidToAdd)) {
                    // Remove the facoid in the set
                    ShapoidFree(&facoid);
                    GSetIterGetElem(&iter)->_data = NULL;
                } else if (!FacoidAlignedIsOutsideFacoidAligned(facoidToAdd,
                facoid)) {
                    // Split the facoid to be added into new facoids
                    // which cover the non intersecting area

```

```

    GSet* split =
        FacoidAlignedSplitExcludingFacoidAligned(facoidToAdd,
            facoid);
    GSetAppendSet(&setToAdd, split);
    GSetFree(&split);
    // Delete the splitted facoid
    ShapoidFree(&facoidToAdd);
    GSetIterGetElem(&iterToAdd)->_data = NULL;
    // And skip the other facoids in the set
    flagSkip = true;
}
// Else the facoid to add is completely outside, leave it as
// it is
} while (!flagSkip && GSetIterStep(&iter));
} while (GSetIterStep(&iterToAdd));
// When we arrive here the set 'setToAdd' contains the facoids
// to be added to 'set'
GSetAppendSet(set, &setToAdd);
// There may have been deleted facoid, ensure the resulting set
// is clean by removeing null pointer
GSetRemoveAll(set, NULL);
// Free memory used by the set of sub facoid to add
GSetFlush(&setToAdd);
}
}

// Check if the Facoid 'that' is completely included into the Facoid
// 'facoid'
// Both Facoid must be aligned with the coordinates system
// 'that' and 'facoid' must have same dimensions and have
// same dimensions
// Return true if it is included, false else
bool FacoidAlignedIsInsideFacoidAligned(Facoid* that, Facoid* facoid) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (facoid == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'facoid' is null");
        PBErrCatch(ShapoidErr);
    }
    if (ShapoidGetDim(that) != ShapoidGetDim(facoid)) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' and 'facoid' have different dimensions (%d==%d)",
            ShapoidGetDim(that), ShapoidGetDim(facoid));
        PBErrCatch(ShapoidErr);
    }
}
#endif
// Check inclusion for each axis
for (int iAxis = ShapoidGetDim(that); iAxis--;)
    // If 'that' is outside 'facoid' for this axis
    if (VecGet(ShapoidPos(that), iAxis) <
        VecGet(ShapoidPos(facoid), iAxis) ||
        VecGet(ShapoidPos(that), iAxis) +
        VecGet(ShapoidAxis(that, iAxis), iAxis) >
        VecGet(ShapoidPos(facoid), iAxis) +
        VecGet(ShapoidAxis(facoid, iAxis), iAxis))
        // Return false

```

```

        return false;
    // If we reach here it means 'that' is inside 'facoid', return true
    return true;
}

// Check if the Facoid 'that' is completely excluded from the Facoid
// 'facoid'
// Both Facoid must be aligned with the coordinates system and have
// same dimensions
// Return true if it is excluded, false else
bool FacoidAlignedIsOutsideFacoidAligned(Facoid* that,
    Facoid* facoid) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (facoid == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'facoid' is null");
            PBErrCatch(ShapoidErr);
        }
        if (ShapoidGetDim(that) != ShapoidGetDim(facoid)) {
            ShapoidErr->_type = PBErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'that' and 'facoid' have different dimensions (%d==%d)",
                ShapoidGetDim(that), ShapoidGetDim(facoid));
            PBErrCatch(ShapoidErr);
        }
    #endif
    // Check exclusion for each axis
    for (int iAxis = ShapoidGetDim(that); iAxis--;)
        // If 'that' is outside 'facoid' for this axis
        if (VecGet(ShapoidPos(that), iAxis) >
            VecGet(ShapoidPos(facoid), iAxis) +
            VecGet(ShapoidAxis(facoid, iAxis), iAxis) - PB_MATH_EPSILON ||
            VecGet(ShapoidPos(that), iAxis) +
            VecGet(ShapoidAxis(that, iAxis), iAxis) <
            VecGet(ShapoidPos(facoid), iAxis) + PB_MATH_EPSILON)
            // Return true
            return true;
    // If we reach here it means 'that' intersects 'facoid', return false
    return false;
}

// Get a GSet of Facoid aligned with coordinates system covering the
// Facoid 'that' except for area in the Facoid 'facoid'
// Both Facoid must be aligned with the coordinates system and have
// same dimensions
GSet* FacoidAlignedSplitExcludingFacoidAligned(Facoid* that,
    Facoid* facoid) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (facoid == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'facoid' is null");
            PBErrCatch(ShapoidErr);
        }
    #endif
}

```



```

}
if (ShapoidGetDim(that) != ShapoidGetDim(facoid)) {
    ShapoidErr->_type = PErrTypeInvalidArg;
    sprintf(ShapoidErr->_msg,
        "'that' and 'facoid' have different dimensions (%d==%d)",
        ShapoidGetDim(that), ShapoidGetDim(facoid));
    PErrCatch(ShapoidErr);
}
#endif
// Ladies and Gentleman, here comes the infamous "Gruyere Algorithm"
// Declare the result GSet
GSet* set = GSetCreate();
// Declare a clone of the original facoid
Facoid* src = FacoidClone(that);
// For each axis
for (int iAxis = ShapoidGetDim(that); iAxis--;) {
    // If 'src' has area on the left of 'facoid' along this axis
    if (VecGet(ShapoidPos(src), iAxis) <
        VecGet(ShapoidPos(facoid), iAxis)) {
        // Create the facoid made of this area
        Facoid* sub = FacoidClone(src);
        VecSet(ShapoidAxis(sub, iAxis), iAxis,
            VecGet(ShapoidPos(facoid), iAxis) -
            VecGet(ShapoidPos(src), iAxis));
        // Add it to the result set
        GSetAppend(set, sub);
        // Chop the added area from 'src'
        VecSet(ShapoidAxis(src, iAxis), iAxis,
            VecGet(ShapoidAxis(src, iAxis), iAxis) -
            VecGet(ShapoidAxis(sub, iAxis), iAxis));
        VecSet(ShapoidPos(src), iAxis,
            VecGet(ShapoidPos(facoid), iAxis));
    }
    // If 'src' has area on the right of 'facoid' along this axis
    if (VecGet(ShapoidPos(src), iAxis) +
        VecGet(ShapoidAxis(src, iAxis), iAxis) >
        VecGet(ShapoidPos(facoid), iAxis) +
        VecGet(ShapoidAxis(facoid, iAxis), iAxis)) {
        // Create the facoid made of this area
        Facoid* sub = FacoidClone(src);
        VecSet(ShapoidAxis(sub, iAxis), iAxis,
            (VecGet(ShapoidPos(src), iAxis) +
            VecGet(ShapoidAxis(src, iAxis), iAxis)) -
            (VecGet(ShapoidPos(facoid), iAxis) +
            VecGet(ShapoidAxis(facoid, iAxis), iAxis)));
        VecSet(ShapoidPos(sub), iAxis,
            VecGet(ShapoidPos(facoid), iAxis) +
            VecGet(ShapoidAxis(facoid, iAxis), iAxis));
        // Add it to the result set
        GSetAppend(set, sub);
        // Chop the added area from 'src'
        VecSet(ShapoidAxis(src, iAxis), iAxis,
            VecGet(ShapoidAxis(src, iAxis), iAxis) -
            VecGet(ShapoidAxis(sub, iAxis), iAxis));
    }
    // If 'src' is empty
    if (ISEQUALF(VecGet(ShapoidAxis(src, iAxis), iAxis), 0.0))
        // End the loop
        iAxis = 0;
}
// Free memory
ShapoidFree(&src);

```

```

    // Return the result set
    return set;
}

// ----- ShapoidIter

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

// Step the ShapoidIter 'that' for a Facoid
// Return false if the iterator is at its end and couldn't be stepped
bool _ShapoidIterStepFacoid(ShapoidIter* that);

// Step the ShapoidIter 'that' for a Pyramidoid
// Return false if the iterator is at its end and couldn't be stepped
bool _ShapoidIterStepPyramidoid(ShapoidIter* that);

// Step the ShapoidIter 'that' for a Spheroid
// Return false if the iterator is at its end and couldn't be stepped
bool _ShapoidIterStepSpheroid(ShapoidIter* that);

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

// Create a new iterator on the Shapoid 'shap' with a step of 'delta'
// (step on the internal coordinates of the Shapoid)
// The iterator is initialized and ready to be stepped
ShapoidIter _ShapoidIterCreateStatic(Shapoid* shap, VecFloat* delta) {
#ifdef BUILDMODE == 0
    if (shap == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'shap' is null");
        PErrCatch(ShapoidErr);
    }
    if (delta == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'delta' is null");
        PErrCatch(ShapoidErr);
    }
    if (VecGetDim(delta) != ShapoidGetDim(shap)) {
        ShapoidErr->_type = PErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'delta' dimensions and 'shap' dimensions don't match (%d==%d)",
            VecGetDim(delta), ShapoidGetDim(shap));
        PErrCatch(ShapoidErr);
    }
}
#endif
    // Declare the new iterator
    ShapoidIter iter;
    // Set properties
    iter._shap = shap;
    iter._delta = VecClone(delta);
    iter._pos = VecFloatCreate(VecGetDim(delta));
    // Init the position
    ShapoidIterInit(&iter);
    // Return the new iterator
    return iter;
}

// Free the memory used by the ShapoidIter 'that'
void ShapoidIterFreeStatic(ShapoidIter* that) {
    // Check argument
    if (that == NULL)
        // Nothing to do

```

```

    return;
    // Free memory
    VecFree(&(that->_delta));
    VecFree(&(that->_pos));
}

// Reinitialise the ShapoidIter 'that' to its starting position
void ShapoidIterInit(ShapoidIter* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Initialise according to the type of Shapoid
    switch(ShapoidGetType(that->_shap)) {
        case ShapoidTypeFacoid:
        case ShapoidTypePyramidoid:
            VecSetNull(that->_pos);
            break;
        case ShapoidTypeSpheroid:
            VecSetNull(that->_pos);
            VecSet(that->_pos, VecGetDim(that->_pos) - 1, -0.5);
            break;
        default:
            break;
    }
}

// Step the ShapoidIter 'that'
// Return false if the iterator is at its end and couldn't be stepped
bool ShapoidIterStep(ShapoidIter* that) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Declare a flag for the return value
    bool flag = true;
    // Step according to the type of Shapoid
    switch(ShapoidGetType(that->_shap)) {
        case ShapoidTypeFacoid:
            flag = _ShapoidIterStepFacoid(that);
            break;
        case ShapoidTypePyramidoid:
            flag = _ShapoidIterStepPyramidoid(that);
            break;
        case ShapoidTypeSpheroid:
            flag = _ShapoidIterStepSpheroid(that);
            break;
        default:
            break;
    }
    return flag;
}

// Step the ShapoidIter 'that' for a Facoid
// Return false if the iterator is at its end and couldn't be stepped
bool _ShapoidIterStepFacoid(ShapoidIter* that) {

```

```

// Declare a variable for the returned flag
bool ret = true;
// Declare a variable to memorise the dimension currently increasing
int iDim = VecGetDim(that->_pos) - 1;
// Declare a flag for the loop condition
bool flag = true;
// Increment
do {
    VecSet(that->_pos, iDim,
        VecGet(that->_pos, iDim) + VecGet(that->_delta, iDim));
    if (VecGet(that->_pos, iDim) > 1.0 + PBMath_EPSILON) {
        VecSet(that->_pos, iDim, 0.0);
        --iDim;
    } else {
        flag = false;
    }
} while (iDim >= 0 && flag == true);
if (iDim == -1)
    ret = false;
// Return the flag
return ret;
}

// Step the ShapoidIter 'that' for a Pyramidoid
// Return false if the iterator is at its end and couldn't be stepped
bool _ShapoidIterStepPyramidoid(ShapoidIter* that) {
    // Declare a variable for the returned flag
    bool ret = true;
    // Declare a variable to memorise the dimension currently increasing
    int iDim = VecGetDim(that->_pos) - 1;
    // Declare a flag for the loop condition
    bool flag = true;
    // Increment
    do {
        VecSet(that->_pos, iDim,
            VecGet(that->_pos, iDim) + VecGet(that->_delta, iDim));
        float sum = 0.0;
        for (int iAxis = VecGetDim(that->_pos); iAxis--;)
            sum += VecGet(that->_pos, iAxis);
        if (sum > 1.0 + PBMath_EPSILON) {
            VecSet(that->_pos, iDim, 0.0);
            --iDim;
        } else {
            flag = false;
        }
    } while (iDim >= 0 && flag == true);
    if (iDim == -1)
        ret = false;
    // Return the flag
    return ret;
}

// Step the ShapoidIter 'that' for a Spheroid
// Return false if the iterator is at its end and couldn't be stepped
bool _ShapoidIterStepSpheroid(ShapoidIter* that) {
    // Declare a variable to memorise the dimension currently increasing
    int iDim = 0;
    // Declare a flag for the loop condition
    bool flag = true;
    // Declare a variable to memorize the norm of the current position
    float norm = VecNorm(that->_pos);
    // Ladies and Gentleman, here comes the infamous "Worm Algorithm"

```

```

// Increment from the first axis
for (iDim = 0; iDim < VecGetDim(that->_pos) && flag == true; ++iDim) {
    float prevNorm = norm;
    // Try to step in this axis
    VecSet(that->_pos, iDim,
        VecGet(that->_pos, iDim) + VecGet(that->_delta, iDim));
    // Get the norm of the new position
    norm = VecNorm(that->_pos);
    // If we have just jumped over the boundary
    if (prevNorm < 0.5 - PBMath_EPSILON &&
        norm >= 0.5 + PBMath_EPSILON) {
        // Correct the step to reach exactly the boundary
        // Set the current axis to relax the constraint
        VecSet(that->_pos, iDim, 0.0);
        // Calculate the value for this axis which put back the position
        // at the boundary of the Spheroid (on positive side as we want
        // the end of the boundary)
        norm = VecNorm(that->_pos);
        float val = 0.5 * sqrt(-4.0 * (fastpow(norm, 2) - 0.25));
        VecSet(that->_pos, iDim, val);
        // Correct the norm
        norm = 0.5;
        // We could step on this axis, stop here
        flag = false;
        // To cancel the increment in the loop
        --iDim;
    } else {
        // If the new position is out of bound it means we reach the
        // boundary
        if (norm >= 0.5 + PBMath_EPSILON) {
            // Set the current axis to 0.0 to relax the constraint on
            // other axis
            VecSet(that->_pos, iDim, 0.0);
        } else {
            // We could step on this axis, stop here
            flag = false;
            // To cancel the increment in the loop
            --iDim;
        }
    }
}
// If we could step, it has modified the constraint on the previous
// axis which must then be updated
if (flag == false) {
    --iDim;
    // If there is actually a previous axis
    if (iDim >= 0) {
        // Calculate the value for this axis which put back the position
        // at the boundary of the Spheroid (on negative side as we will
        // increment from there)
        float val = VecGet(that->_pos, iDim) +
            0.5 * (-2.0 * VecGet(that->_pos, iDim) -
                sqrt(4.0 * (fastpow(VecGet(that->_pos, iDim), 2) -
                    fastpow(norm, 2) + 0.25)));
        VecSet(that->_pos, iDim, val);
    }
}
// Return the negative of the flag
return !flag;
}

```

3.2 shapoid-inline.c

```
// ===== SHAPOID-INLINE.C =====

// ----- Shapoid

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

// Get the dimension of the Shapoid
#if BUILDMODE != 0
inline
#endif
int _ShapoidGetDim(Shapoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Return the dimension
    return that->_dim;
}

// Get the dimension of the Shapoid
#if BUILDMODE != 0
inline
#endif
ShapoidType _ShapoidGetType(Shapoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Return the type
    return that->_type;
}

// Get the type of the Shapoid as a string
// Return a pointer to a constant string (not to be freed)
#if BUILDMODE != 0
inline
#endif
const char* _ShapoidGetTypeAsString(Shapoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Return the type
    return ShapoidTypeString[that->_type];
}

// Return a VecFloat equals to the position of the Shapoid
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidGetPos(Shapoid* that) {
```

```

#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
#endif
    // Return a clone of the position
    return VecClone(that->_pos);
}

// Return a VecFloat equals to the 'dim'-th axis of the Shapoid
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidGetAxis(Shapoid* that, int dim) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
    if (dim < 0 || dim >= that->_dim) {
        ShapoidErr->_type = PErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "Axis' index is invalid (0<=%d<%d)",
            dim, that->_dim);
        PErrCatch(ShapoidErr);
    }
#endif
    // Return a clone of the axis
    return VecClone(that->_axis[dim]);
}

// Return the position of the Shapoid
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidPos(Shapoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
#endif
    // Return the position
    return that->_pos;
}

// Return the 'dim'-th axis of the Shapoid
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidAxis(Shapoid* that, int dim) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
    if (dim < 0 || dim >= that->_dim) {
        ShapoidErr->_type = PErrTypeInvalidArg;
    }
#endif
}

```

```

        sprintf(ShapoidErr->_msg, "Axis' index is invalid (0<=%d<%d)",
            dim, that->_dim);
        PBErriCatch(ShapoidErr);
    }
#endif
    // Return the axis
    return that->_axis[dim];
}

// Set the position of the Shapoid to 'pos'
#if BUILDMODE != 0
inline
#endif
void _ShapoidSetPos(Shapoid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErriTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErriCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErriTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PBErriCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != that->_dim) {
        ShapoidErr->_type = PBErriTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            VecGetDim(pos), that->_dim);
        PBErriCatch(ShapoidErr);
    }
#endif
    // Set the position
    VecCopy(that->_pos, pos);
}

// Set the 'dim'-th axis of the Shapoid to 'v'
#if BUILDMODE != 0
inline
#endif
void _ShapoidSetAxis(Shapoid* that, int dim, VecFloat* v) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErriTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErriCatch(ShapoidErr);
    }
    if (v == NULL) {
        ShapoidErr->_type = PBErriTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'v' is null");
        PBErriCatch(ShapoidErr);
    }
    if (dim < 0 || dim >= that->_dim) {
        ShapoidErr->_type = PBErriTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "Axis' index is invalid (0<=%d<%d)",
            dim, that->_dim);
        PBErriCatch(ShapoidErr);
    }
    if (VecGetDim(v) != that->_dim) {
        ShapoidErr->_type = PBErriTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'v' 's dimension is invalid (%d==%d)",
            dim, VecGetDim(v));
    }
#endif
}

```



```

        PBErrCatch(ShapoidErr);
    }
#endif
    // Set the axis
    VecCopy(that->_axis[dim], v);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Translate the Shapoid by 'v'
#if BUILDMODE != 0
inline
#endif
void _ShapoidTranslate(Shapoid* that, VecFloat* v) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (v == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'v' is null");
        PBErrCatch(ShapoidErr);
    }
    if (VecGetDim(v) != that->_dim) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'v' 's dimension is invalid (%d==%d)",
            that->_dim, VecGetDim(v));
        PBErrCatch(ShapoidErr);
    }
#endif
    // Translate the position
    VecOp(that->_pos, 1.0, v, 1.0);
}

// Scale the Shapoid by 'v' (each axis is multiplied by v[iAxis])
#if BUILDMODE != 0
inline
#endif
void _ShapoidScaleVector(Shapoid* that, VecFloat* v) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (v == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'v' is null");
        PBErrCatch(ShapoidErr);
    }
    if (VecGetDim(v) != that->_dim) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'v' 's dimension is invalid (%d==%d)",
            that->_dim, VecGetDim(v));
        PBErrCatch(ShapoidErr);
    }
#endif
    // Scale each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecScale(that->_axis[iAxis], VecGet(v, iAxis));
}

```

```

    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Scale the Shapoid by 'c'
#if BUILDMODE != 0
inline
#endif
void _ShapoidScaleScalar(Shapoid* that, float c) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Scale each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecScale(that->_axis[iAxis], c);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Scale the Shapoid by 'v' (each axis is multiplied by v[iAxis])
// and translate the Shapoid such as its center after scaling
// is at the same position than before scaling
#if BUILDMODE != 0
inline
#endif
void _ShapoidGrowVector(Shapoid* that, VecFloat* v) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (v == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'v' is null");
        PBErrCatch(ShapoidErr);
    }
    if (VecGetDim(v) != that->_dim) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'v' 's dimension is invalid (%d==%d)",
            that->_dim, VecGetDim(v));
        PBErrCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PBErrCatch(ShapoidErr);
    }
#endif
    // If the shapoid is a spheroid
    if (that->_type == ShapoidTypeSpheroid) {
        // Scale
        ShapoidScale(that, v);
    }
    // Else, the shapoid is not a spheroid
    else {
        // Memorize the center

```

```

    VecFloat* centerA = ShapoidGetCenter(that);
    // Scale
    ShapoidScale(that, v);
    // Reposition to keep center at the same position
    VecFloat* centerB = ShapoidGetCenter(that);
    VecOp(centerA, 1.0, centerB, -1.0);
    VecOp(that->_pos, 1.0, centerA, 1.0);
    VecFree(&centerA);
    VecFree(&centerB);
}
// Update the SysLinEq
ShapoidUpdateSysLinEqImport(that);
}

// Scale the Shapoid by 'c'
// and translate the Shapoid such as its center after scaling
// is at the same position than before scaling
#if BUILDMODE != 0
inline
#endif
void _ShapoidGrowScalar(Shapoid* that, float c) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (that->_type != ShapoidTypeFacoid &&
            that->_type != ShapoidTypeSpheroid &&
            that->_type != ShapoidTypePyramidoid) {
            ShapoidErr->_type = PBErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
            PBErrCatch(ShapoidErr);
        }
    #endif
    // If the shapoid is a spheroid
    if (that->_type == ShapoidTypeSpheroid) {
        // Scale
        ShapoidScale(that, c);
    } else {
        // Memorize the center
        VecFloat* centerA = ShapoidGetCenter(that);
        // Scale
        ShapoidScale(that, c);
        // Reposition to keep center at the same position
        VecFloat* centerB = ShapoidGetCenter(that);
        VecOp(centerA, 1.0, centerB, -1.0);
        VecOp(that->_pos, 1.0, centerA, 1.0);
        VecFree(&centerA);
        VecFree(&centerB);
    }
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 2 by 'theta' (in radians, CCW)
// relatively to its center
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotCenter(Shapoid* that, float theta) {

```

```

#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (that->_dim != 2) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' 's dimension is invalid (%d==2)", that->_dim);
        PBErrCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PBErrCatch(ShapoidErr);
    }
#endif
    // If it's a spheroid
    if (that->_type == ShapoidTypeSpheroid) {
        // Rotate each axis
        for (int iAxis = that->_dim; iAxis--;)
            VecRot(that->_axis[iAxis], theta);
        // Else, it's not a spheroid
    } else {
        VecFloat* center = ShapoidGetCenter(that);
        // Rotate each axis
        for (int iAxis = that->_dim; iAxis--;)
            VecRot(that->_axis[iAxis], theta);
        // Reposition the origin
        VecFloat* v = VecGetOp(that->_pos, 1.0, center, -1.0);
        VecRot(v, theta);
        VecOp(v, 1.0, center, 1.0);
        VecCopy(that->_pos, v);
        VecFree(&center);
        VecFree(&v);
    }
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 2 by 'theta' (in radians, CCW)
// relatively to its position
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotStart(Shapoid* that, float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (that->_dim != 2) {
            ShapoidErr->_type = PBErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'that' 's dimension is invalid (%d==2)", that->_dim);
            PBErrCatch(ShapoidErr);
        }
    #endif
}

```

```

    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRot(that->_axis[iAxis], theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 2 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotOrigin(Shapoid* that, float theta) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (that->_dim != 2) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' 's dimension is invalid (%d==2)", that->_dim);
        PBErrCatch(ShapoidErr);
    }
#endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRot(that->_axis[iAxis], theta);
    // Reposition the origin
    VecRot(that->_pos, theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its center around 'axis'
// 'axis' must be normalized
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotAxisCenter(Shapoid* that, VecFloat3D* axis, float theta) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (axis == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'axis' is null");
        PBErrCatch(ShapoidErr);
    }
    if (VecGetDim(axis) != 3) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'axis' 's dimension is invalid (%d==3)", VecGetDim(axis));
        PBErrCatch(ShapoidErr);
    }
    if (that->_dim != 3) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,

```

```

        "'that' 's dimension is invalid (%d==3)", that->_dim);
    PBErCatch(ShapoidErr);
}
if (that->_type != ShapoidTypeFacoid &&
    that->_type != ShapoidTypeSpheroid &&
    that->_type != ShapoidTypePyramidoid) {
    ShapoidErr->_type = PBErTypeInvalidArg;
    sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
    PBErCatch(ShapoidErr);
}
#endif
// If it's a spheroid
if (that->_type == ShapoidTypeSpheroid) {
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotAxis(that->_axis[iAxis], axis, theta);
    // Else, it's not a spheroid
} else {
    VecFloat* center = ShapoidGetCenter(that);
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotAxis(that->_axis[iAxis], axis, theta);
    // Reposition the origin
    VecFloat* v = VecGetOp(that->_pos, 1.0, center, -1.0);
    VecRotAxis(v, axis, theta);
    VecOp(v, 1.0, center, 1.0);
    VecCopy(that->_pos, v);
    VecFree(&center);
    VecFree(&v);
}
// Update the SysLinEq
ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around 'axis'
// 'axis' must be normalized
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotAxisStart(Shapoid* that, VecFloat3D* axis,
    float theta) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErCatch(ShapoidErr);
    }
    if (axis == NULL) {
        ShapoidErr->_type = PBErTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'axis' is null");
        PBErCatch(ShapoidErr);
    }
    if (that->_dim != 3) {
        ShapoidErr->_type = PBErTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' 's dimension is invalid (%d==3)", that->_dim);
        PBErCatch(ShapoidErr);
    }
    if (VecGetDim(axis) != 3) {
        ShapoidErr->_type = PBErTypeInvalidArg;
        sprintf(ShapoidErr->_msg,

```

```

        "'axis' 's dimension is invalid (%d==3)", VecGetDim(axis));
        PBErCatch(ShapoidErr);
    }
#endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotAxis(that->_axis[iAxis], axis, theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around 'axis'
// 'axis' must be normalized
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotAxisOrigin(Shapoid* that, VecFloat3D* axis,
    float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErCatch(ShapoidErr);
        }
        if (axis == NULL) {
            ShapoidErr->_type = PBErTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'axis' is null");
            PBErCatch(ShapoidErr);
        }
        if (that->_dim != 3) {
            ShapoidErr->_type = PBErTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'that' 's dimension is invalid (%d==3)", that->_dim);
            PBErCatch(ShapoidErr);
        }
        if (VecGetDim(axis) != 3) {
            ShapoidErr->_type = PBErTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'axis' 's dimension is invalid (%d==3)", VecGetDim(axis));
            PBErCatch(ShapoidErr);
        }
    #endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotAxis(that->_axis[iAxis], axis, theta);
    // Reposition the origin
    VecRotAxis(that->_pos, axis, theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its center around X
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotXCenter(Shapoid* that, float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErTypeNullPointer;

```

```

    sprintf(ShapoidErr->_msg, "'that' is null");
    PBErCatch(ShapoidErr);
}
if (that->_dim != 3) {
    ShapoidErr->_type = PBErTypeInvalidArg;
    sprintf(ShapoidErr->_msg,
        "'that' 's dimension is invalid (%d==3)", that->_dim);
    PBErCatch(ShapoidErr);
}
if (that->_type != ShapoidTypeFacoid &&
    that->_type != ShapoidTypeSpheroid &&
    that->_type != ShapoidTypePyramidoid) {
    ShapoidErr->_type = PBErTypeInvalidArg;
    sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
    PBErCatch(ShapoidErr);
}
#endif
// If it's a spheroid
if (that->_type == ShapoidTypeSpheroid) {
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotX(that->_axis[iAxis], theta);
    // Else, it's not a spheroid
} else {
    VecFloat* center = ShapoidGetCenter(that);
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotX(that->_axis[iAxis], theta);
    // Reposition the origin
    VecFloat* v = VecGetOp(that->_pos, 1.0, center, -1.0);
    VecRotX(v, theta);
    VecOp(v, 1.0, center, 1.0);
    VecCopy(that->_pos, v);
    VecFree(&center);
    VecFree(&v);
}
// Update the SysLinEq
ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around X
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotXStart(Shapoid* that,
    float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErCatch(ShapoidErr);
        }
        if (that->_dim != 3) {
            ShapoidErr->_type = PBErTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'that' 's dimension is invalid (%d==3)", that->_dim);
            PBErCatch(ShapoidErr);
        }
    #endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)

```



```

        VecRotX(that->_axis[iAxis], theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around X
#ifdef BUILDMODE != 0
inline
#endif
void _ShapoidRotXOrigin(Shapoid* that,
    float theta) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (that->_dim != 3) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' 's dimension is invalid (%d==3)", that->_dim);
        PBErrCatch(ShapoidErr);
    }
#endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotX(that->_axis[iAxis], theta);
    // Reposition the origin
    VecRotX(that->_pos, theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its center around Y
#ifdef BUILDMODE != 0
inline
#endif
void _ShapoidRotYCenter(Shapoid* that, float theta) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (that->_dim != 3) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' 's dimension is invalid (%d==3)", that->_dim);
        PBErrCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PBErrCatch(ShapoidErr);
    }
#endif
    // If it's a spheroid

```

```

    if (that->_type == ShapoidTypeSpheroid) {
        // Rotate each axis
        for (int iAxis = that->_dim; iAxis--;)
            VecRotY(that->_axis[iAxis], theta);
        // Else, it's not a spheroid
    } else {
        VecFloat* center = ShapoidGetCenter(that);
        // Rotate each axis
        for (int iAxis = that->_dim; iAxis--;)
            VecRotY(that->_axis[iAxis], theta);
        // Reposition the origin
        VecFloat* v = VecGetOp(that->_pos, 1.0, center, -1.0);
        VecRotY(v, theta);
        VecOp(v, 1.0, center, 1.0);
        VecCopy(that->_pos, v);
        VecFree(&center);
        VecFree(&v);
    }
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around Y
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotYStart(Shapoid* that,
    float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (that->_dim != 3) {
            ShapoidErr->_type = PBErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'that' 's dimension is invalid (%d=3)", that->_dim);
            PBErrCatch(ShapoidErr);
        }
    #endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotY(that->_axis[iAxis], theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around Y
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotYOrigin(Shapoid* that,
    float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
    #endif

```

```

    }
    if (that->_dim != 3) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' 's dimension is invalid (%d==3)", that->_dim);
        PBErrCatch(ShapoidErr);
    }
#endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotY(that->_axis[iAxis], theta);
    // Reposition the origin
    VecRotY(that->_pos, theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its center around Z
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotZCenter(Shapoid* that, float theta) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (that->_dim != 3) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg,
            "'that' 's dimension is invalid (%d==3)", that->_dim);
        PBErrCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PBErrCatch(ShapoidErr);
    }
#endif
    // If it's a spheroid
    if (that->_type == ShapoidTypeSpheroid) {
        // Rotate each axis
        for (int iAxis = that->_dim; iAxis--;)
            VecRotZ(that->_axis[iAxis], theta);
        // Else, it's not a spheroid
    } else {
        VecFloat* center = ShapoidGetCenter(that);
        // Rotate each axis
        for (int iAxis = that->_dim; iAxis--;)
            VecRotZ(that->_axis[iAxis], theta);
        // Reposition the origin
        VecFloat* v = VecGetOp(that->_pos, 1.0, center, -1.0);
        VecRotZ(v, theta);
        VecOp(v, 1.0, center, 1.0);
        VecCopy(that->_pos, v);
        VecFree(&center);
        VecFree(&v);
    }
}

```

```

    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to its position around Z
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotZStart(Shapoid* that,
    float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (that->_dim != 3) {
            ShapoidErr->_type = PBErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'that' 's dimension is invalid (%d==3)", that->_dim);
            PBErrCatch(ShapoidErr);
        }
    #endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotZ(that->_axis[iAxis], theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Rotate the Shapoid of dimension 3 by 'theta' (in radians, CCW)
// relatively to the origin of the global coordinates system
// around Z
#if BUILDMODE != 0
inline
#endif
void _ShapoidRotZOrigin(Shapoid* that,
    float theta) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (that->_dim != 3) {
            ShapoidErr->_type = PBErrTypeInvalidArg;
            sprintf(ShapoidErr->_msg,
                "'that' 's dimension is invalid (%d==3)", that->_dim);
            PBErrCatch(ShapoidErr);
        }
    #endif
    // Rotate each axis
    for (int iAxis = that->_dim; iAxis--;)
        VecRotZ(that->_axis[iAxis], theta);
    // Reposition the origin
    VecRotZ(that->_pos, theta);
    // Update the SysLinEq
    ShapoidUpdateSysLinEqImport(that);
}

// Convert the coordinates of 'pos' from standard coordinate system

```

```

// toward the Shapoid coordinates system
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidImportCoord(Shapoid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PErrCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != that->_dim) {
        ShapoidErr->_type = PErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            that->_dim, VecGetDim(pos));
        PErrCatch(ShapoidErr);
    }
#endif
    // Update the system solver for the requested position
    VecFloat* v = VecGetOp(pos, 1.0, that->_pos, -1.0);
    SysLinEqSetV(that->_sysLinEqImport, v);
    // Solve the system
    VecFloat* res = SysLinEqSolve(that->_sysLinEqImport);
    // Free memory
    VecFree(&v);
    // return the result
    return res;
}
#if BUILDMODE != 0
inline
#endif

// Convert the coordinates of 'pos' from the Shapoid coordinates system
// toward standard coordinate system
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidExportCoord(Shapoid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PErrCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != that->_dim) {
        ShapoidErr->_type = PErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            that->_dim, VecGetDim(pos));
        PErrCatch(ShapoidErr);
    }
#endif
    // Allocate memory for the result

```

```

VecFloat* res = VecClone(that->_pos);
for (int dim = that->_dim; dim--;)
    VecOp(res, 1.0, that->_axis[dim], VecGet(pos, dim));
// Return the result
return res;
}

// Get the center of the shapoid in standard coordinate system
#if BUILDMODE != 0
inline
#endif
VecFloat* _ShapoidGetCenter(Shapoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PErrCatch(ShapoidErr);
    }
#elseif
    if (ShapoidGetType(that) == ShapoidTypeFacoid)
        return FacoidGetCenter((Facoid*)that);
    else if (ShapoidGetType(that) == ShapoidTypePyramidoid)
        return PyramidoidGetCenter((Pyramidoid*)that);
    else if (ShapoidGetType(that) == ShapoidTypeSpheroid)
        return SpheroidGetCenter((Spheroid*)that);
    else
        return NULL;
#endif
}

#if BUILDMODE != 0
inline
#endif
VecFloat* FacoidGetCenter(Facoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PErrCatch(ShapoidErr);
    }
#elseif
    // Declare a variable to memorize the result in Shapoid
    // coordinate system
    VecFloat* coord = VecFloatCreate(ShapoidGetDim(that));
    // For each dimension
    for (int dim = ShapoidGetDim(that); dim--;)
        VecSet(coord, dim, 0.5);
    // Convert the coordinates in standard coordinate system
    VecFloat* res = ShapoidExportCoord(that, coord);
    // Free memory
    VecFree(&coord);
    // Return the result
    return res;
#endif
}

#if BUILDMODE != 0

```

```

inline
#endif
VecFloat* PyramidoidGetCenter(Pyramidoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Declare a variable to memorize the result in Shapoid
    // coordinate system
    VecFloat* coord = VecFloatCreate(ShapoidGetDim(that));
    // For each dimension
    for (int dim = ShapoidGetDim(that); dim--;)
        VecSet(coord, dim, 1.0 / (1.0 + ShapoidGetDim(that)));
    // Convert the coordinates in standard coordinate system
    VecFloat* res = ShapoidExportCoord(that, coord);
    // Free memory
    VecFree(&coord);
    // Return the result
    return res;
}

#if BUILDMODE != 0
inline
#endif
VecFloat* SpheroidGetCenter(Spheroid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    // Declare a variable to memorize the result in Shapoid
    // coordinate system
    VecFloat* coord = VecFloatCreate(ShapoidGetDim(that));
    // Convert the coordinates in standard coordinate system
    VecFloat* res = ShapoidExportCoord(that, coord);
    // Free memory
    VecFree(&coord);
    // Return the result
    return res;
}

// Check if shapoid 'that' and 'tho' are equals
#if BUILDMODE != 0
inline
#endif
bool _ShapoidIsEqual(Shapoid* that, Shapoid* tho) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (tho == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'tho' is null");
        PBErrCatch(ShapoidErr);
    }
}

```

```

#endif
// Check the dimension, type and position
if (that->_dim != tho->_dim ||
    that->_type != tho->_type ||
    VecIsEqual(that->_pos, tho->_pos) == false)
    return false;
// Check the axis
for (int i = that->_dim; i--;)
    if (VecIsEqual(that->_axis[i], tho->_axis[i]) == false)
        return false;
// Return the success code
return true;
}

// Update the system of linear equation used to import coordinates
#if BUILDMODE != 0
inline
#endif
void ShapoidUpdateSysLinEqImport(Shapoid* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    VecShort2D dim = VecShortCreateStatic2D();
    // Set a pointer to the matrix in the SysLinEq
    MatFloat* mat = MatClone(that->_sysLinEqImport->_M);
    // Set the values of the matrix
    for (VecSet(&dim, 0, 0); VecGet(&dim, 0) < that->_dim;
        VecSet(&dim, 0, VecGet(&dim, 0) + 1)) {
        for (VecSet(&dim, 1, 0); VecGet(&dim, 1) < that->_dim;
            VecSet(&dim, 1, VecGet(&dim, 1) + 1)) {
            MatSet(mat, &dim, VecGet(that->_axis[VecGet(&dim, 0)],
                VecGet(&dim, 1)));
        }
    }
    // Update the SysLinEq
    SysLinEqSetM(that->_sysLinEqImport, mat);
    // Free memory
    MatFree(&mat);
}

// Return true if 'pos' (in stand coordinate system) is inside the
// Shapoid
// Else return false
#if BUILDMODE != 0
inline
#endif
bool _ShapoidIsPosInside(Shapoid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PBErrCatch(ShapoidErr);
    }
}

```



```

    if (VecGetDim(pos) != that->_dim) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            that->_dim, VecGetDim(pos));
        PBErrCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PBErrCatch(ShapoidErr);
    }
#endif
    // If the Shapoid is a Facoid
    if (that->_type == ShapoidTypeFacoid) {
        return FacoidIsPosInside((Facoid*)that, pos);
    }
    // Else, if the Shapoid is a Pyramidoid
    else if (that->_type == ShapoidTypePyramidoid) {
        return PyramidoidIsPosInside((Pyramidoid*)that, pos);
    }
    // Else, if the Shapoid is a Spheroid
    else if (that->_type == ShapoidTypeSpheroid) {
        return SpheroidIsPosInside((Spheroid*)that, pos);
    }
    else
        return false;
}

#if BUILDMODE != 0
inline
#endif
bool FacoidIsPosInside(Facoid* that, VecFloat* pos) {
    #if BUILDMODE == 0
        if (that == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'that' is null");
            PBErrCatch(ShapoidErr);
        }
        if (pos == NULL) {
            ShapoidErr->_type = PBErrTypeNullPointer;
            sprintf(ShapoidErr->_msg, "'pos' is null");
            PBErrCatch(ShapoidErr);
        }
    #endif
    if (VecGetDim(pos) != ShapoidGetDim(that)) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            ShapoidGetDim(that), VecGetDim(pos));
        PBErrCatch(ShapoidErr);
    }
}
#endif
// Get the coordinates of pos in the Shapoid coordinate system
VecFloat* coord = ShapoidImportCoord(that, pos);
// Declare a variable to memorize the result
bool ret = false;
// pos is in the Shapoid if all the coord in Shapoid coord
// system are in [0.0, 1.0]
ret = true;
for (int dim = ShapoidGetDim(that); dim-- && ret == true;) {
    float v = VecGet(coord, dim);
    if (v < 0.0 || v > 1.0)
        ret = false;
}
// Free memory

```

```

    VecFree(&coord);
    // Return the result
    return ret;
}

#if BUILDMODE != 0
inline
#endif
bool PyramidoidIsPosInside(Pyramidoid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PBErrCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != ShapoidGetDim(that)) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            ShapoidGetDim(that), VecGetDim(pos));
        PBErrCatch(ShapoidErr);
    }
#endif
    // Get the coordinates of pos in the Shapoid coordinate system
    VecFloat* coord = ShapoidImportCoord(that, pos);
    // Declare a variable to memorize the result
    bool ret = false;
    // pos is in the Shapoid if all the coord in Shapoid coord
    // system are in [0.0, 1.0] and their sum is in [0.0, 1.0]
    ret = true;
    float sum = 0.0;
    for (int dim = ShapoidGetDim(that); dim-- && ret == true;) {
        float v = VecGet(coord, dim);
        sum += v;
        if (v < 0.0 || v > 1.0)
            ret = false;
    }
    if (ret == true && sum > 1.0)
        ret = false;
    // Free memory
    VecFree(&coord);
    // Return the result
    return ret;
}

#if BUILDMODE != 0
inline
#endif
bool SpheroidIsPosInside(Spheroid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
    }
#endif
}

```

```

        PBErCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != ShapoidGetDim(that)) {
        ShapoidErr->_type = PBErTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            ShapoidGetDim(that), VecGetDim(pos));
        PBErCatch(ShapoidErr);
    }
#endif
    // Get the coordinates of pos in the Shapoid coordinate system
    VecFloat* coord = ShapoidImportCoord(that, pos);
    // Declare a variable to memorize the result
    bool ret = false;
    // pos is in the Shapoid if its norm is in [0.0, 0.5]
    float norm = VecNorm(coord);
    if (norm <= 0.5)
        ret = true;
    // Free memory
    VecFree(&coord);
    // Return the result
    return ret;
}

// Get the depth value in the Shapoid of 'pos'
// The depth is defined as follow: the point with depth equals 1.0 is
// the farthest point from the surface of the Shapoid (inside it),
// points with depth equals to 0.0 are point on the surface of the
// Shapoid. Depth is continuous and derivable over the volume of the
// Shapoid
#if BUILDMODE != 0
inline
#endif
float _ShapoidGetPosDepth(Shapoid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PBErCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != that->_dim) {
        ShapoidErr->_type = PBErTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            that->_dim, VecGetDim(pos));
        PBErCatch(ShapoidErr);
    }
    if (that->_type != ShapoidTypeFacoid &&
        that->_type != ShapoidTypeSpheroid &&
        that->_type != ShapoidTypePyramidoid) {
        ShapoidErr->_type = PBErTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "No implementation for 'that' 's type");
        PBErCatch(ShapoidErr);
    }
#endif
    // If the Shapoid is a Facoid
    if (that->_type == ShapoidTypeFacoid) {
        return FacoidGetPosDepth((Facoid*)that, pos);
    }
    // Else, if the Shapoid is a Pyramidoid

```

```

    } else if (that->_type == ShapoidTypePyramidoid) {
        return PyramidoidGetPosDepth((Pyramidoid*)that, pos);
    // Else, if the Shapoid is a Spheroid
    } else if (that->_type == ShapoidTypeSpheroid) {
        return SpheroidGetPosDepth((Spheroid*)that, pos);
    } else {
        return 0.0;
    }
}

#ifdef BUILDMODE != 0
inline
#endif
float FacoidGetPosDepth(Facoid* that, VecFloat* pos) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PBErrCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != ShapoidGetDim(that)) {
        ShapoidErr->_type = PBErrTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            ShapoidGetDim(that), VecGetDim(pos));
        PBErrCatch(ShapoidErr);
    }
#endif
    // Get the coordinates of pos in the Shapoid coordinate system
    VecFloat* coord = ShapoidImportCoord(that, pos);
    // Declare a variable to memorize the result
    float ret = 1.0;
    for (int dim = ShapoidGetDim(that); dim-- && ret > PBMath_EPSILON;) {
        float v = VecGet(coord, dim);
        if (v < 0.0 || VecGet(coord, dim) > 1.0)
            ret = 0.0;
        else
            ret *= 1.0 - pow(0.5 - v, 2.0) * 4.0;
    }
    // Free memory
    VecFree(&coord);
    // Return the result
    return ret;
}

#ifdef BUILDMODE != 0
inline
#endif
float PyramidoidGetPosDepth(Pyramidoid* that, VecFloat* pos) {
#ifdef BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
    }
#endif
}

```

```

        PBErCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != ShapoidGetDim(that)) {
        ShapoidErr->_type = PBErTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            ShapoidGetDim(that), VecGetDim(pos));
        PBErCatch(ShapoidErr);
    }
#endif
    // Get the coordinates of pos in the Shapoid coordinate system
    VecFloat* coord = ShapoidImportCoord(that, pos);
    // Declare a variable to memorize the result
    float ret = 1.0;
    float sum = 0.0;
    bool flag = true;
    for (int dim = ShapoidGetDim(that); dim-- && ret > PBMath_EPSILON;) {
        float v = VecGet(coord, dim);
        sum += v;
        if (v < 0.0 || v > 1.0)
            flag = false;
    }
    if (flag == true && sum > 1.0)
        flag = false;
    if (flag == false)
        ret = 0.0;
    else {
        ret = 1.0;
        for (int dim = ShapoidGetDim(that); dim--;) {
            float z = 0.0;
            for (int d = ShapoidGetDim(that); d--;)
                if (d != dim)
                    z += VecGet(coord, d);
            ret *=
                (1.0 - 4.0 * pow(0.5 - VecGet(coord, dim) / (1.0 - z), 2.0));
        }
    }
    // Free memory
    VecFree(&coord);
    // Return the result
    return ret;
}

#if BUILDMODE != 0
inline
#endif
float SpheroidGetPosDepth(Spheroid* that, VecFloat* pos) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErCatch(ShapoidErr);
    }
    if (pos == NULL) {
        ShapoidErr->_type = PBErTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'pos' is null");
        PBErCatch(ShapoidErr);
    }
    if (VecGetDim(pos) != ShapoidGetDim(that)) {
        ShapoidErr->_type = PBErTypeInvalidArg;
        sprintf(ShapoidErr->_msg, "'pos' 's dimension is invalid (%d==%d)",
            ShapoidGetDim(that), VecGetDim(pos));
        PBErCatch(ShapoidErr);
    }

```

```

    }
#endif
    // Get the coordinates of pos in the Shapoid coordinate system
    VecFloat* coord = ShapoidImportCoord(that, pos);
    // Declare a variable to memorize the result
    float ret = 0.0;
    float norm = VecNorm(coord);
    if (norm <= 0.5)
        ret = 1.0 - norm * 2.0;
    // Free memory
    VecFree(&coord);
    // Return the result
    return ret;
}

// ----- ShapoidIter

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

// Return the current position in Shapoid coordinates of the
// ShapoidIter 'that'
#if BUILDMODE != 0
inline
#endif
VecFloat* ShapoidIterGetInternal(ShapoidIter* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    return VecClone(that->_pos);
}

// Return the current position in standard coordinates of the
// ShapoidIter 'that'
#if BUILDMODE != 0
inline
#endif
VecFloat* ShapoidIterGetExternal(ShapoidIter* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    return ShapoidExportCoord(that->_shap, that->_pos);
}

// Set the attached Shapoid of the ShapoidIter 'that' to 'shap'
// The iterator is reset to its initial position
#if BUILDMODE != 0
inline
#endif
void _ShapoidIterSetShapoid(ShapoidIter* that, Shapoid* shap) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
}

```

```

    }
#endif
    that->_shap = shap;
}

// Get the Shapoid of the ShapoidIter 'that'
#if BUILDMODE != 0
inline
#endif
Shapoid* ShapoidIterShapoid(ShapoidIter* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    return that->_shap;
}

// Set the delta of the ShapoidIter 'that' to a copy of 'delta'
#if BUILDMODE != 0
inline
#endif
void _ShapoidIterSetDelta(ShapoidIter* that, VecFloat* delta) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    VecFree(&(that->_delta));
    that->_delta = VecClone(delta);
}

// Get the delta of the ShapoidIter 'that'
#if BUILDMODE != 0
inline
#endif
VecFloat* ShapoidIterDelta(ShapoidIter* that) {
#if BUILDMODE == 0
    if (that == NULL) {
        ShapoidErr->_type = PBErrTypeNullPointer;
        sprintf(ShapoidErr->_msg, "'that' is null");
        PBErrCatch(ShapoidErr);
    }
#endif
    return that->_delta;
}

```

4 Makefile

```

#directory
PBERRDIR=../PBErr
PBMATHDIR=../PBMath
GSETDIR=../GSet

# 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$(PBERRDIR)/ -I$(PBATHDIR)/ -I$(GSETDIR)/
BUILDOPTIONS=$(BUILDPARAM) $(INCPATH)

# compiler
COMPILER=gcc

#rules
all : main

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

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

shapoid.o : shapoid.c shapoid.h shapoid-inline.c $(PBATHDIR)/pbmath.h $(GSETDIR)/gset.h $(PBERRDIR)/pberr.h Makefile
$(COMPILER) $(BUILDOPTIONS) -c shapoid.c

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

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

gset.o : $(GSETDIR)/gset.c $(GSETDIR)/gset-inline.c $(GSETDIR)/gset.h Makefile $(PBERRDIR)/pberr.h
$(COMPILER) $(BUILDOPTIONS) -c $(GSETDIR)/gset.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 "shapoid.h"

#define RANDOMSEED 0

void UnitTestCreateCloneIsEqualFree() {
    int dim = 3;

```



```

Shapoid* facoid = ShapoidCreate(dim, ShapoidTypeFacoid);
if (facoid == NULL || facoid->_dim != dim ||
    facoid->_type != ShapoidTypeFacoid || facoid->_pos == NULL ||
    VecGetDim(facoid->_pos) != dim || facoid->_sysLinEqImport == NULL ||
    facoid->_axis == NULL) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidCreate failed");
    PBErrCatch(ShapoidErr);
}
for (int iDim = dim; iDim--;) {
    if (ISEQUALF(VecGet(facoid->_pos, iDim), 0.0) == false ||
        facoid->_axis[iDim] == NULL ||
        VecGetDim(facoid->_axis[iDim]) != dim) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidCreate failed");
        PBErrCatch(ShapoidErr);
    }
    for (int jDim = dim; jDim--;) {
        if ((iDim == jDim &&
            ISEQUALF(VecGet(facoid->_axis[iDim], jDim), 1.0) == false) ||
            (iDim != jDim &&
            ISEQUALF(VecGet(facoid->_axis[iDim], jDim), 0.0) == false)) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidCreate failed");
            PBErrCatch(ShapoidErr);
        }
    }
    if (ISEQUALF(VecGet(facoid->_sysLinEqImport->_V, iDim),
        0.0) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidCreate failed");
        PBErrCatch(ShapoidErr);
    }
}
VecShort2D u = VecShortCreateStatic2D();
VecSet(&u, 0, dim); VecSet(&u, 1, dim);
VecShort2D v = VecShortCreateStatic2D();
do {
    if ((VecGet(&v, 0) == VecGet(&v, 1) &&
        ISEQUALF(MatGet(facoid->_sysLinEqImport->_M, &v), 1.0) == false) ||
        (VecGet(&v, 0) != VecGet(&v, 1) &&
        ISEQUALF(MatGet(facoid->_sysLinEqImport->_M, &v), 0.0) == false) ||
        (VecGet(&v, 0) == VecGet(&v, 1) &&
        ISEQUALF(MatGet(facoid->_sysLinEqImport->_Minv, &v),
            1.0) == false) ||
        (VecGet(&v, 0) != VecGet(&v, 1) &&
        ISEQUALF(MatGet(facoid->_sysLinEqImport->_Minv, &v),
            0.0) == false)) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidCreate failed");
        PBErrCatch(ShapoidErr);
    }
} while (VecStep(&v, &u));
Shapoid* clone = ShapoidClone(facoid);
if (facoid->_dim != clone->_dim ||
    facoid->_type != clone->_type ||
    VecIsEqual(facoid->_pos, clone->_pos) == false ||
    MatIsEqual(facoid->_sysLinEqImport->_M,
        clone->_sysLinEqImport->_M) == false ||
    MatIsEqual(facoid->_sysLinEqImport->_Minv,
        clone->_sysLinEqImport->_Minv) == false ||
    VecIsEqual(facoid->_sysLinEqImport->_V,

```

```

        clone->_sysLinEqImport->_V) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidClone failed");
    PBErrCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    if (VecIsEqual(facoid->_axis[i], clone->_axis[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidClone failed");
        PBErrCatch(ShapoidErr);
    }
}
if (ShapoidIsEqual(facoid, clone) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidIsEqual failed");
    PBErrCatch(ShapoidErr);
}
clone->_type = ShapoidTypePyramidoid;
if (ShapoidIsEqual(facoid, clone) == true) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidIsEqual failed");
    PBErrCatch(ShapoidErr);
}
clone->_type = facoid->_type;
clone->_dim = dim + 1;
if (ShapoidIsEqual(facoid, clone) == true) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidIsEqual failed");
    PBErrCatch(ShapoidErr);
}
clone->_dim = facoid->_dim;
VecSet(clone->_pos, 0, 1.0);
if (ShapoidIsEqual(facoid, clone) == true) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidIsEqual failed");
    PBErrCatch(ShapoidErr);
}
VecSet(clone->_pos, 0, 0.0);
VecSet(clone->_axis[0], 0, 2.0);
if (ShapoidIsEqual(facoid, clone) == true) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidIsEqual failed");
    PBErrCatch(ShapoidErr);
}
VecSet(clone->_axis[0], 0, 1.0);
ShapoidFree(&facoid);
if (facoid != NULL) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidFree failed");
    PBErrCatch(ShapoidErr);
}
ShapoidFree(&clone);
printf("UnitTestCreateCloneIsEqualFree OK\n");
}

void UnitTestLoadSavePrint() {
    int dim = 3;
    Facoid* facoid = FacoidCreate(dim);
    FILE* file = fopen("./facoid.txt", "w");
    if (ShapoidSave(facoid, file) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidSave failed");
    }
}

```

```

        PBErCatch(ShapoidErr);
    }
    fclose(file);
    file = fopen("./facoid.txt", "r");
    Facoid* load = FacoidCreate(dim);
    if (ShapoidLoad(&load, file) == false) {
        ShapoidErr->_type = PBErTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidLoad failed");
        PBErCatch(ShapoidErr);
    }
    fclose(file);
    if (ShapoidIsEqual(facoid, load) == false) {
        ShapoidErr->_type = PBErTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidLoad/Save failed");
        PBErCatch(ShapoidErr);
    }
    ShapoidPrintln(facoid, stdout);
    ShapoidFree(&facoid);
    ShapoidFree(&load);
    printf("UnitTestLoadSavePrint OK\n");
}

void UnitTestGetSetTypeDimPosAxis() {
    int dim = 3;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    if (ShapoidGetType(facoid) != ShapoidTypeFacoid ||
        ShapoidGetType(pyramidoid) != ShapoidTypePyramidoid ||
        ShapoidGetType(spheroid) != ShapoidTypeSpheroid) {
        ShapoidErr->_type = PBErTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetType failed");
        PBErCatch(ShapoidErr);
    }
    if (ShapoidGetDim(facoid) != dim) {
        ShapoidErr->_type = PBErTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetDim failed");
        PBErCatch(ShapoidErr);
    }
    VecFloat* v = VecFloatCreate(dim);
    VecFloat* u = ShapoidGetPos(facoid);
    if (VecIsEqual(v, u) == false) {
        ShapoidErr->_type = PBErTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetPos failed");
        PBErCatch(ShapoidErr);
    }
    VecFree(&u);
    for (int i = dim; i--;) {
        u = ShapoidGetAxis(facoid, i);
        for (int j = dim; j--;)
            if ((i == j && ISEQUALF(VecGet(u, j), 1.0) == false) ||
                (i != j && ISEQUALF(VecGet(u, j), 0.0) == false)) {
                ShapoidErr->_type = PBErTypeUnitTestFailed;
                sprintf(ShapoidErr->_msg, "ShapoidGetAxis failed");
                PBErCatch(ShapoidErr);
            }
        VecFree(&u);
    }
    for (int i = dim; i--;)
        VecSet(v, i, (float)i);
    ShapoidSetPos(facoid, v);
    if (VecIsEqual(v, ShapoidPos(facoid)) == false) {

```

```

    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidSetPos failed");
    PBErrCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    VecSetNull(v);
    VecSet(v, i, 2.0);
    ShapoidSetAxis(facoid, i, v);
    if (VecIsEqual(v, ShapoidAxis(facoid, i)) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidSetAxis failed");
        PBErrCatch(ShapoidErr);
    }
}
VecFree(&v);
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestGetSetTypeDimPosAxis OK\n");
}

void UnitTestTranslateScaleGrow() {
    int dim = 2;
    Facoid* facoid = FacoidCreate(dim);
    VecFloat* v = VecFloatCreate(dim);
    for (int i = dim; i--;)
        VecSet(v, i, 1.0);
    ShapoidTranslate(facoid, v);
    if (VecIsEqual(v, ((Shapoid*)facoid)->_pos) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidTranslate failed");
        PBErrCatch(ShapoidErr);
    }
    float scale = 2.0;
    ShapoidScale(facoid, scale);
    VecSetNull(v);
    VecSetNull(((Shapoid*)facoid)->_pos);
    if (VecIsEqual(v, ((Shapoid*)facoid)->_pos) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "_ShapoidScaleScalar failed");
        PBErrCatch(ShapoidErr);
    }
    for (int i = dim; i--;) {
        for (int j = dim; j--;)
            if (i == j)
                VecSet(v, j, scale);
            else
                VecSet(v, j, 0.0);
        if (VecIsEqual(v, ((Shapoid*)facoid)->_axis[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "_ShapoidScaleScalar failed");
            PBErrCatch(ShapoidErr);
        }
    }
}
for (int i = dim; i--;)
    VecSet(v, i, 1.0 + (float)i);
ShapoidScale(facoid, v);
VecSetNull(v);
if (VecIsEqual(v, ((Shapoid*)facoid)->_pos) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "_ShapoidScaleVector failed");
    PBErrCatch(ShapoidErr);
}

```

```

}
for (int i = dim; i--;) {
    for (int j = dim; j--;)
        if (i == j)
            VecSet(v, j, scale * (1.0 + (float)i));
        else
            VecSet(v, j, 0.0);
    if (VecIsEqual(v, ((Shapoid*)facoid)->_axis[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "_ShapoidScaleVector failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidFree(&facoid);
facoid = FacoidCreate(dim);
scale = 2.0;
ShapoidGrow(facoid, scale);
for (int i = dim; i--;)
    VecSet(v, i, -0.5);
if (VecIsEqual(v, ((Shapoid*)facoid)->_pos) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "_ShapoidGrowScalar failed");
    PBErrCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    for (int j = dim; j--;)
        if (i == j)
            VecSet(v, j, scale);
        else
            VecSet(v, j, 0.0);
    if (VecIsEqual(v, ((Shapoid*)facoid)->_axis[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "_ShapoidGrowScalar failed");
        PBErrCatch(ShapoidErr);
    }
}
Pyramidoid* pyramidoid = PyramidoidCreate(dim);
VecFloat* centerA = ShapoidGetCenter(pyramidoid);
ShapoidGrow(pyramidoid, scale);
VecFloat* centerB = ShapoidGetCenter(pyramidoid);
if (VecIsEqual(centerA, centerB) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "_ShapoidGrowScalar failed");
    PBErrCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    for (int j = dim; j--;)
        if (i == j)
            VecSet(v, j, scale);
        else
            VecSet(v, j, 0.0);
    if (VecIsEqual(v, ((Shapoid*)pyramidoid)->_axis[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "_ShapoidGrowScalar failed");
        PBErrCatch(ShapoidErr);
    }
}
VecFree(&centerA);
VecFree(&centerB);
Spheroid* spheroid = SpheroidCreate(dim);
ShapoidGrow(spheroid, scale);
VecSetNull(v);

```

```

if (VecIsEqual(v, ((Shapoid*)spheroid)->_pos) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "_ShapoidGrowScalar failed");
    PBErrCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    for (int j = dim; j--;)
        if (i == j)
            VecSet(v, j, scale);
        else
            VecSet(v, j, 0.0);
    if (VecIsEqual(v, ((Shapoid*)spheroid)->_axis[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "_ShapoidGrowScalar failed");
        PBErrCatch(ShapoidErr);
    }
}
VecFloat* scalev = VecFloatCreate(dim);
for (int i = dim; i--;)
    VecSet(scalev, i, 1.0 + (float)i);
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
facoid = FacoidCreate(dim);
ShapoidGrow(facoid, scalev);
float pa[2] = {0.000, -0.500};
for (int i = dim; i--;)
    VecSet(v, i, pa[i]);
if (VecIsEqual(v, ((Shapoid*)facoid)->_pos) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "_ShapoidGrowVector failed");
    PBErrCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    for (int j = dim; j--;)
        if (i == j)
            VecSet(v, j, VecGet(scalev, i));
        else
            VecSet(v, j, 0.0);
    if (VecIsEqual(v, ((Shapoid*)facoid)->_axis[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "_ShapoidGrowVector failed");
        PBErrCatch(ShapoidErr);
    }
}
pyramidoid = PyramidoidCreate(dim);
centerA = ShapoidGetCenter(pyramidoid);
ShapoidGrow(pyramidoid, scalev);
centerB = ShapoidGetCenter(pyramidoid);
if (VecIsEqual(centerA, centerB) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "_ShapoidGrowVector failed");
    PBErrCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    for (int j = dim; j--;)
        if (i == j)
            VecSet(v, j, VecGet(scalev, i));
        else
            VecSet(v, j, 0.0);
    if (VecIsEqual(v, ((Shapoid*)pyramidoid)->_axis[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
    }
}

```

```

        sprintf(ShapoidErr->_msg, "_ShapoidGrowVector failed");
        PBErCatch(ShapoidErr);
    }
}
VecFree(&centerA);
VecFree(&centerB);
spheroid = SpheroidCreate(dim);
ShapoidGrow(spheroid, scalev);
VecSetNull(v);
if (VecIsEqual(v, ((Shapoid*)spheroid)->_pos) == false) {
    ShapoidErr->_type = PBErTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "_ShapoidGrowVector failed");
    PBErCatch(ShapoidErr);
}
for (int i = dim; i--;) {
    for (int j = dim; j--;)
        if (i == j)
            VecSet(v, j, VecGet(scalev, i));
        else
            VecSet(v, j, 0.0);
    if (VecIsEqual(v, ((Shapoid*)spheroid)->_axis[i]) == false) {
        ShapoidErr->_type = PBErTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "_ShapoidGrowVector failed");
        PBErCatch(ShapoidErr);
    }
}
VecFree(&scalev);
VecFree(&v);
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestTranslateScaleGrow OK\n");
}

void UnitTestRotate() {
    int dim = 2;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    float theta = PBMath_HALFPI;
    ShapoidRotCenter(facoid, theta);
    float pb[2] = {1.0, 0.0};
    float pc[2] = {0.0, 1.0};
    float pd[2] = {-1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pb[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
                pc[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
                pd[i]) == false) {
            ShapoidErr->_type = PBErTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotCenter failed");
            PBErCatch(ShapoidErr);
        }
    }
    ShapoidRotCenter(pyramidoid, theta);
    float pe[2] = {0.6666667, 0.0};
    float pf[2] = {0.0, 1.0};
    float pg[2] = {-1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pe[i]) == false ||

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        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
        pf[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        pg[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotCenter failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotCenter(spheroid, theta);
float ph[2] = {0.0, 0.0};
float pi[2] = {0.0, 1.0};
float pj[2] = {-1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        ph[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        pi[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        pj[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotCenter failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotOrigin(facoid, theta);
float pk[2] = {0.0, 1.0};
float pl[2] = {-1.0, 0.0};
float pm[2] = {0.0, -1.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pk[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
        pl[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
        pm[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotOrigin(pyramidoid, theta);
float pn[2] = {0.0, 0.6666667};
float po[2] = {-1.0, 0.0};
float pp[2] = {0.0, -1.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
        pn[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
        po[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        pp[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotOrigin(spheroid, theta);
float pq[2] = {0.0, 0.0};
float pr[2] = {-1.0, 0.0};
float ps[2] = {0.0, -1.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),

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        pq[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        pr[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        ps[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotStart(facoid, theta);
float pt[2] = {0.0, 1.0};
float pu[2] = {0.0, -1.0};
float pv[2] = {1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pt[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
        pu[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
        pv[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotStart(pyramidoid, theta);
float pw[2] = {0.0, 0.6666667};
float px[2] = {0.0, -1.0};
float py[2] = {1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
        pw[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
        px[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        py[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotStart(spheroid, theta);
float pz[2] = {0.0, 0.0};
float paa[2] = {0.0, -1.0};
float pab[2] = {1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        pz[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        paa[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        pab[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestRotate OK\n");
}

```

```

void UnitTestRotateAxis() {
    int dim = 3;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    float theta = PBMATH_HALFPI;
    VecFloat3D axis = VecFloatCreateStatic3D();
    VecSet(&axis, 0, 1.0); VecSet(&axis, 1, 1.0); VecSet(&axis, 2, 1.0);
    VecNormalise(&axis);
    ShapoidRotAxisCenter(facoid, &axis, theta);
    float pb[3] = {0.0, 0.0, 0.0};
    float pc[3] = {0.333333, 0.910684, -0.244017};
    float pd[3] = {-0.244017, 0.333333, 0.910684};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pb[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
                pc[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
                pd[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotAxisCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotAxisCenter(pyramidoid, &axis, theta);
    float pe[3] = {0.000000, 0.000000, 0.000000};
    float pf[3] = {0.333333, 0.910684, -0.244017};
    float pg[3] = {-0.244017, 0.333333, 0.910684};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pe[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
                pf[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
                pg[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotAxisCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotAxisCenter(spheroid, &axis, theta);
    float ph[3] = {0.0, 0.0, 0.0};
    float pi[3] = {0.333333, 0.910684, -0.244017};
    float pj[3] = {-0.244017, 0.333333, 0.910684};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
            ph[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
                pi[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
                pj[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotAxisCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotAxisOrigin(facoid, &axis, theta);
    float pk[3] = {0.0, 0.0, 0.0};
    float pl[3] = {-0.333333, 0.666667, 0.666667};
    float pm[3] = {0.666667, -0.333333, 0.666667};
    for (int i = dim; i--;) {

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    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pk[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
            pl[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
            pm[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotAxisOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotAxisOrigin(pyramidoid, &axis, theta);
float pn[3] = {0.0, 0.0, 0.0};
float po[3] = {-0.333333, 0.666667, 0.666667};
float pp[3] = {0.666667, -0.333333, 0.666667};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
        pn[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
            po[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
            pp[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotAxisOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotAxisOrigin(spheroid, &axis, theta);
float pq[3] = {0.0, 0.0, 0.0};
float pr[3] = {-0.333333, 0.666667, 0.666667};
float ps[3] = {0.666667, -0.333333, 0.666667};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        pq[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
            pr[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
            ps[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotAxisOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotAxisStart(facoid, &axis, theta);
float pt[3] = {0.0, 0.0, 0.0};
float pu[3] = {0.333333, -0.244017, 0.910683};
float pv[3] = {0.910683, 0.333333, -0.244017};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pt[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
            pu[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
            pv[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotAxisStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotAxisStart(pyramidoid, &axis, theta);
float pw[3] = {0.0, 0.0, 0.0};
float px[3] = {0.333333, -0.244017, 0.910683};
float py[3] = {0.910683, 0.333333, -0.244017};
for (int i = dim; i--;) {

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        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pw[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
            px[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
            py[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotAxisStart failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotAxisStart(spheroid, &axis, theta);
    float pz[3] = {0.0, 0.0, 0.0};
    float paa[3] = {0.333333, -0.244017, 0.910683};
    float pab[3] = {0.910683, 0.333333, -0.244017};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
            pz[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
            paa[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
            pab[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotAxisStart failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidFree(&facoid);
    ShapoidFree(&pyramidoid);
    ShapoidFree(&spheroid);
    printf("UnitTestRotateAxis OK\n");
}

void UnitTestRotateX() {
    int dim = 3;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    float theta = PBMATH_HALFP;
    ShapoidRotXCenter(facoid, theta);
    float pb[3] = {0.0, 1.0, 0.0};
    float pc[3] = {1.0, 0.0, 0.0};
    float pd[3] = {0.0, 0.0, 1.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pb[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
            pc[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
            pd[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotXCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotXCenter(pyramidoid, theta);
    float pe[3] = {0.0, 0.5, 0.0};
    float pf[3] = {1.0, 0.0, 0.0};
    float pg[3] = {0.0, 0.0, 1.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pe[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),

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        pf[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        pg[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotXCenter failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotXCenter(spheroid, theta);
float ph[3] = {0.0, 0.0, 0.0};
float pi[3] = {1.0, 0.0, 0.0};
float pj[3] = {0.0, 0.0, 1.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        ph[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        pi[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        pj[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotXCenter failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotXOrigin(facoid, theta);
float pk[3] = {0.0, 0.0, 1.0};
float pl[3] = {1.0, 0.0, 0.0};
float pm[3] = {0.0, -1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pk[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
        pl[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
        pm[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotXOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotXOrigin(pyramidoid, theta);
float pn[3] = {0.0, 0.0, 0.5};
float po[3] = {1.0, 0.0, 0.0};
float pp[3] = {0.0, -1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
        pn[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
        po[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        pp[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotXOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotXOrigin(spheroid, theta);
float pq[3] = {0.0, 0.0, 0.0};
float pr[3] = {1.0, 0.0, 0.0};
float ps[3] = {0.0, -1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        pq[i]) == false ||

```

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    ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
    pr[i]) == false ||
    ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
    ps[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotX0origin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotXStart(facoid, theta);
float pt[3] = {0.0, 0.0, 1.0};
float pu[3] = {1.0, 0.0, 0.0};
float pv[3] = {0.0, 0.0, -1.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pt[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
        pu[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
        pv[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotXStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotXStart(pyramidoid, theta);
float pw[3] = {0.0, 0.0, 0.5};
float px[3] = {1.0, 0.0, 0.0};
float py[3] = {0.0, 0.0, -1.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
        pw[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
        px[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        py[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotXStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotXStart(spheroid, theta);
float pz[3] = {0.0, 0.0, 0.0};
float paa[3] = {1.0, 0.0, 0.0};
float pab[3] = {0.0, 0.0, -1.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        pz[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        paa[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        pab[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotXStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestRotateX OK\n");
}

```

```

void UnitTestRotateY() {
    int dim = 3;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    float theta = PBMath_HALFPI;
    ShapoidRotYCenter(facoid, theta);
    float pb[3] = {0.0, 0.0, 1.0};
    float pc[3] = {0.0, 0.0, -1.0};
    float pd[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pb[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
                pc[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
                pd[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotYCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotYCenter(pyramidoid, theta);
    float pe[3] = {0.0, 0.0, 0.5};
    float pf[3] = {0.0, 0.0, -1.0};
    float pg[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pe[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
                pf[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
                pg[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotYCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotYCenter(spheroid, theta);
    float ph[3] = {0.0, 0.0, 0.0};
    float pi[3] = {0.0, 0.0, -1.0};
    float pj[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
            ph[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
                pi[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
                pj[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotYCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotY0Origin(facoid, theta);
    float pk[3] = {1.0, 0.0, 0.0};
    float pl[3] = {-1.0, 0.0, 0.0};
    float pm[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pk[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
                pl[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),

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        pm[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotY0Origin failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotY0Origin(pyramidoid, theta);
    float pn[3] = {0.5, 0.0, 0.0};
    float po[3] = {-1.0, 0.0, 0.0};
    float pp[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pn[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
            po[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
            pp[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotY0Origin failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotY0Origin(spheroid, theta);
    float pq[3] = {0.0, 0.0, 0.0};
    float pr[3] = {-1.0, 0.0, 0.0};
    float ps[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
            pq[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
            pr[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
            ps[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotY0Origin failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotYStart(facoid, theta);
    float pt[3] = {1.0, 0.0, 0.0};
    float pu[3] = {0.0, 0.0, 1.0};
    float pv[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pt[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
            pu[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
            pv[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotYStart failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotYStart(pyramidoid, theta);
    float pw[3] = {0.5, 0.0, 0.0};
    float px[3] = {0.0, 0.0, 1.0};
    float py[3] = {0.0, 1.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pw[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
            px[i]) == false ||

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        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        py[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotYStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotYStart(spheroid, theta);
float pz[3] = {0.0, 0.0, 0.0};
float paa[3] = {0.0, 0.0, 1.0};
float pab[3] = {0.0, 1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        pz[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        paa[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        pab[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotYStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestRotateY OK\n");
}

void UnitTestRotateZ() {
    int dim = 3;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    float theta = PBMATH_HALFPI;
    ShapoidRotZCenter(facoid, theta);
    float pb[3] = {1.0, 0.0, 0.0};
    float pc[3] = {0.0, 1.0, 0.0};
    float pd[3] = {-1.0, 0.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pb[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
            pc[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
            pd[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidRotZCenter failed");
            PBErrCatch(ShapoidErr);
        }
    }
    ShapoidRotZCenter(pyramidoid, theta);
    float pe[3] = {0.5, 0.0, 0.0};
    float pf[3] = {0.0, 1.0, 0.0};
    float pg[3] = {-1.0, 0.0, 0.0};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
            pe[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
            pf[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
            pg[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;

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        sprintf(ShapoidErr->_msg, "ShapoidRotZCenter failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotZCenter(spheroid, theta);
float ph[3] = {0.0, 0.0, 0.0};
float pi[3] = {0.0, 1.0, 0.0};
float pj[3] = {-1.0, 0.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        ph[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        pi[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        pj[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotZCenter failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotZOrigin(facoid, theta);
float pk[3] = {0.0, 1.0, 0.0};
float pl[3] = {-1.0, 0.0, 0.0};
float pm[3] = {0.0, -1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pk[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
        pl[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
        pm[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotZOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotZOrigin(pyramidoid, theta);
float pn[3] = {0.0, 0.5, 0.0};
float po[3] = {-1.0, 0.0, 0.0};
float pp[3] = {0.0, -1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
        pn[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
        po[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
        pp[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotZOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotZOrigin(spheroid, theta);
float pq[3] = {0.0, 0.0, 0.0};
float pr[3] = {-1.0, 0.0, 0.0};
float ps[3] = {0.0, -1.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        pq[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
        pr[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
        ps[i]) == false) {

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        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotZOrigin failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotZStart(facoid, theta);
float pt[3] = {0.0, 1.0, 0.0};
float pu[3] = {0.0, -1.0, 0.0};
float pv[3] = {1.0, 0.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)facoid)->_pos, i), pt[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[0], i),
            pu[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)facoid)->_axis[1], i),
            pv[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotZStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotZStart(pyramidoid, theta);
float pw[3] = {0.0, 0.5, 0.0};
float px[3] = {0.0, -1.0, 0.0};
float py[3] = {1.0, 0.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_pos, i),
        pw[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[0], i),
            px[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)pyramidoid)->_axis[1], i),
            py[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotZStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidRotZStart(spheroid, theta);
float pz[3] = {0.0, 0.0, 0.0};
float paa[3] = {0.0, -1.0, 0.0};
float pab[3] = {1.0, 0.0, 0.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)spheroid)->_pos, i),
        pz[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[0], i),
            paa[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)spheroid)->_axis[1], i),
            pab[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidRotZStart failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestRotateZ OK\n");
}

void UnitTestImportExportCoordIsPosInside() {
    int dim = 2;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);

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```

Spheroid* spheroid = SpheroidCreate(dim);
VecFloat* v = VecFloatCreate(dim);
for (int i = dim; i--;)
    VecSet(v, i, 1.0 + (float)i);
ShapoidTranslate(facoid, v);
ShapoidTranslate(pyramidoid, v);
ShapoidTranslate(spheroid, v);
float scale = -2.0;
ShapoidScale(facoid, scale);
ShapoidScale(pyramidoid, scale);
ShapoidScale(spheroid, scale);
int nbTest = 100;
srandom(RANDOMSEED);
for (int iTest = nbTest; iTest--;) {
    VecFloat* posReal = VecFloatCreate(dim);
    for (int i = dim; i--;)
        VecSet(posReal, i, (rnd() - 0.5) * 10.0);
    VecFloat* posShapoidA = ShapoidImportCoord(facoid, posReal);
    bool isInside = ShapoidIsPosInside(facoid, posReal);
    if (VecGet(posShapoidA, 0) >= 0.0 &&
        VecGet(posShapoidA, 0) <= 1.0 &&
        VecGet(posShapoidA, 1) >= 0.0 &&
        VecGet(posShapoidA, 1) <= 1.0) {
        if (isInside == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidIsPosInside failed");
            PBErrCatch(ShapoidErr);
        }
    } else {
        if (isInside == true) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidIsPosInside failed");
            PBErrCatch(ShapoidErr);
        }
    }
    VecOp(posShapoidA, scale, v, 1.0);
    if (VecIsEqual(posReal, posShapoidA) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidImportCoord failed");
        PBErrCatch(ShapoidErr);
    }
    VecFree(&posShapoidA);
    VecFloat* posShapoidB = ShapoidImportCoord(pyramidoid, posReal);
    isInside = ShapoidIsPosInside(pyramidoid, posReal);
    if (VecGet(posShapoidB, 0) >= 0.0 &&
        VecGet(posShapoidB, 0) <= 1.0 &&
        VecGet(posShapoidB, 1) >= 0.0 &&
        VecGet(posShapoidB, 1) <= 1.0 &&
        VecGet(posShapoidB, 0) + VecGet(posShapoidB, 1) <= 1.0) {
        if (isInside == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidIsPosInside failed");
            PBErrCatch(ShapoidErr);
        }
    } else {
        if (isInside == true) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidIsPosInside failed");
            PBErrCatch(ShapoidErr);
        }
    }
    VecOp(posShapoidB, scale, v, 1.0);
}

```

```

if (VecIsEqual(posReal, posShapoidB) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidImportCoord failed");
    PBErrCatch(ShapoidErr);
}
VecFree(&posShapoidB);
VecFloat* posShapoidC = ShapoidImportCoord(spheroid, posReal);
isInside = ShapoidIsPosInside(spheroid, posReal);
if (VecGet(posShapoidC, 0) >= -0.5 &&
    VecGet(posShapoidC, 0) <= 0.5 &&
    VecGet(posShapoidC, 1) >= -0.5 &&
    VecGet(posShapoidC, 1) <= 0.5 &&
    pow(VecGet(posShapoidC, 0), 2.0) +
    pow(VecGet(posShapoidC, 1), 2.0) <= 0.25) {
    if (isInside == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIsPosInside failed");
        PBErrCatch(ShapoidErr);
    }
} else {
    if (isInside == true) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIsPosInside failed");
        PBErrCatch(ShapoidErr);
    }
}
VecOp(posShapoidC, scale, v, 1.0);
if (VecIsEqual(posReal, posShapoidC) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg, "ShapoidImportCoord failed");
    PBErrCatch(ShapoidErr);
}
VecFree(&posShapoidC);
VecFree(&posReal);
}
for (int iTes = nbTest; iTes--;) {
    VecFloat* posShapoid = VecFloatCreate(dim);
    for (int i = dim; i--;)
        VecSet(posShapoid, i, (rnd() - 0.5) * 10.0);
    VecFloat* posRealA = ShapoidExportCoord(facoid, posShapoid);
    VecOp(posRealA, 1.0, v, -1.0);
    VecScale(posRealA, 1.0 / scale);
    if (VecIsEqual(posRealA, posShapoid) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidExportCoord failed");
        PBErrCatch(ShapoidErr);
    }
    VecFree(&posRealA);
    VecFloat* posRealB = ShapoidExportCoord(pyramidoid, posShapoid);
    VecOp(posRealB, 1.0, v, -1.0);
    VecScale(posRealB, 1.0 / scale);
    if (VecIsEqual(posRealB, posShapoid) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidExportCoord failed");
        PBErrCatch(ShapoidErr);
    }
    VecFree(&posRealB);
    VecFloat* posRealC = ShapoidExportCoord(facoid, posShapoid);
    VecOp(posRealC, 1.0, v, -1.0);
    VecScale(posRealC, 1.0 / scale);
    if (VecIsEqual(posRealC, posShapoid) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
    }
}

```

```

        sprintf(ShapoidErr->_msg, "ShapoidExportCoord failed");
        PBErrCatch(ShapoidErr);
    }
    VecFree(&posRealC);
    VecFree(&posShapoid);
}
VecFree(&v);
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestImportExportCoordIsPosInside OK\n");
}

void UnitTestGetBoundingBox() {
    int dim = 2;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    VecFloat* v = VecFloatCreate(dim);
    for (int i = dim; i--;)
        VecSet(v, i, 1.0 + (float)i);
    ShapoidTranslate(facoid, v);
    ShapoidTranslate(pyramidoid, v);
    ShapoidTranslate(spheroid, v);
    float scale = -2.0;
    ShapoidScale(facoid, scale);
    ShapoidScale(pyramidoid, scale);
    ShapoidScale(spheroid, scale);
    float theta = PBMath_QUARTERPI;
    ShapoidRotCenter(facoid, theta);
    ShapoidRotCenter(pyramidoid, theta);
    ShapoidRotCenter(spheroid, theta);
    Facoid* boundA = ShapoidGetBoundingBox(facoid);
    float pa[2] = {-1.414214, -0.414213};
    float pb[2] = {2.828427, 0.0};
    float pc[2] = {0.0, 2.828427};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)boundA)->_pos, i),
            pa[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)boundA)->_axis[0], i),
            pb[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)boundA)->_axis[1], i),
            pc[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidGetBoundingBox failed");
            PBErrCatch(ShapoidErr);
        }
    }
    Facoid* boundB = ShapoidGetBoundingBox(pyramidoid);
    float pd[2] = {-1.08088, 0.86193};
    float pe[2] = {2.82843, 0.0};
    float pf[2] = {0.0, 1.41421};
    for (int i = dim; i--;) {
        if (ISEQUALF(VecGet(((Shapoid*)boundB)->_pos, i), pd[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)boundB)->_axis[0], i),
            pe[i]) == false ||
            ISEQUALF(VecGet(((Shapoid*)boundB)->_axis[1], i),
            pf[i]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidGetBoundingBox failed");
            PBErrCatch(ShapoidErr);
        }
    }
}

```

```

}
Facoid* boundC = ShapoidGetBoundingBox(spheroid);
float pg[2] = {-0.414214, 0.585786};
float ph[2] = {2.828427, 0.0};
float pi[2] = {0.0, 2.828427};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)boundC)->_pos, i), pg[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundC)->_axis[0], i),
            ph[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundC)->_axis[1], i),
            pi[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetBoundingBox failed");
        PBErrCatch(ShapoidErr);
    }
}
}
GSet set = GSetCreateStatic();
GSetPush(&set, facoid);
GSetPush(&set, pyramidoid);
GSetPush(&set, spheroid);
Facoid* boundD = ShapoidGetBoundingBox(&set);
float pj[2] = {-1.41421, -0.41421};
float pk[2] = {3.828427, 0.0};
float pl[2] = {0.0, 3.828427};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)boundD)->_pos, i), pj[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundD)->_axis[0], i),
            pk[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundD)->_axis[1], i),
            pl[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetBoundingBox failed");
        PBErrCatch(ShapoidErr);
    }
}
}
GSetFlush(&set);
VecSet(v, 0, 2.0); VecSet(v, 1, 4.0);
ShapoidSetPos(facoid, v);
ShapoidSetPos(pyramidoid, v);
VecSet(v, 0, 7.0); VecSet(v, 1, 0.0);
ShapoidSetAxis(facoid, 0, v);
ShapoidSetAxis(pyramidoid, 0, v);
VecSet(v, 0, 0.0); VecSet(v, 1, 4.0);
ShapoidSetAxis(facoid, 1, v);
ShapoidSetAxis(pyramidoid, 1, v);
Facoid* boundE = ShapoidGetBoundingBox(facoid);
float pm[2] = {2.0, 4.0};
float pn[2] = {7.0, 0.0};
float po[2] = {0.0, 4.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)boundE)->_pos, i), pm[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundE)->_axis[0], i),
            pn[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundE)->_axis[1], i),
            po[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetBoundingBox failed");
        PBErrCatch(ShapoidErr);
    }
}
}
Facoid* boundF = ShapoidGetBoundingBox(pyramidoid);
float pp[2] = {2.0, 4.0};

```

```

float pq[2] = {7.0, 0.0};
float pr[2] = {0.0, 4.0};
for (int i = dim; i--;) {
    if (ISEQUALF(VecGet(((Shapoid*)boundF)->_pos, i), pp[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundF)->_axis[0], i),
            pq[i]) == false ||
        ISEQUALF(VecGet(((Shapoid*)boundF)->_axis[1], i),
            pr[i]) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetBoundingBox failed");
        PBErrCatch(ShapoidErr);
    }
}
ShapoidFree(&boundA);
ShapoidFree(&boundB);
ShapoidFree(&boundC);
ShapoidFree(&boundD);
ShapoidFree(&boundE);
ShapoidFree(&boundF);
VecFree(&v);
ShapoidFree(&facoid);
ShapoidFree(&pyramidoid);
ShapoidFree(&spheroid);
printf("UnitTestGetBoundingBox OK\n");
}

void UnitTestGetPosDepthCenterCoverage() {
    int dim = 2;
    Facoid* facoid = FacoidCreate(dim);
    Pyramidoid* pyramidoid = PyramidoidCreate(dim);
    Spheroid* spheroid = SpheroidCreate(dim);
    VecFloat* center = ShapoidGetCenter(facoid);
    if (ISEQUALF(VecGet(center, 0), 0.5) == false ||
        ISEQUALF(VecGet(center, 1), 0.5) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCenter failed");
        PBErrCatch(ShapoidErr);
    }
    VecFree(&center);
    center = ShapoidGetCenter(pyramidoid);
    if (ISEQUALF(VecGet(center, 0), 0.333333) == false ||
        ISEQUALF(VecGet(center, 1), 0.333333) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCenter failed");
        PBErrCatch(ShapoidErr);
    }
    VecFree(&center);
    center = ShapoidGetCenter(spheroid);
    if (ISEQUALF(VecGet(center, 0), 0.0) == false ||
        ISEQUALF(VecGet(center, 1), 0.0) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCenter failed");
        PBErrCatch(ShapoidErr);
    }
    VecFree(&center);
    float coverage = ShapoidGetCoverageDelta(facoid, pyramidoid, 0.001);
    if (ISEQUALF(coverage, 1.0) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCoverage failed");
        PBErrCatch(ShapoidErr);
    }
    coverage = ShapoidGetCoverageDelta(pyramidoid, facoid, 0.001);
}

```



```

    if (ISEQUALF(coverage, 0.500499) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCoverage failed");
        PBErrCatch(ShapoidErr);
    }
    coverage = ShapoidGetCoverageDelta(pyramidoid, spheroid, 0.001);
    if (ISEQUALF(coverage, 0.24937) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCoverage failed");
        PBErrCatch(ShapoidErr);
    }
    coverage = ShapoidGetCoverageDelta(spheroid, pyramidoid, 0.001);
    if (ISEQUALF(coverage, 0.39251) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCoverage failed");
        PBErrCatch(ShapoidErr);
    }
    coverage = ShapoidGetCoverageDelta(facoid, spheroid, 0.001);
    if (ISEQUALF(coverage, 0.24937) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCoverage failed");
        PBErrCatch(ShapoidErr);
    }
    coverage = ShapoidGetCoverageDelta(spheroid, facoid, 0.001);
    if (ISEQUALF(coverage, 0.196451) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetCoverage failed");
        PBErrCatch(ShapoidErr);
    }
    VecFloat2D pos = VecFloatCreateStatic2D();
    VecSet(&pos, 0, 0.333333); VecSet(&pos, 1, 0.333333);
    float depth = ShapoidGetPosDepth(facoid, (VecFloat*)&pos);
    if (ISEQUALF(depth, 0.790123) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetPosDepth failed");
        PBErrCatch(ShapoidErr);
    }
    depth = ShapoidGetPosDepth(pyramidoid, (VecFloat*)&pos);
    if (ISEQUALF(depth, 1.0) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetPosDepth failed");
        PBErrCatch(ShapoidErr);
    }
    depth = ShapoidGetPosDepth(spheroid, (VecFloat*)&pos);
    if (ISEQUALF(depth, 0.057192) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidGetPosDepth failed");
        PBErrCatch(ShapoidErr);
    }
    ShapoidFree(&facoid);
    ShapoidFree(&pyramidoid);
    ShapoidFree(&spheroid);
    printf("UnitTestGetPosDepthCenterCoverage OK\n");
}

void UnitTestFacoidAlignedIsInsideFacoidAligned() {
    Facoid* facA = FacoidCreate(2);
    Facoid* facB = FacoidCreate(2);
    VecFloat2D p = VecFloatCreateStatic2D();
    VecFloat2D u = VecFloatCreateStatic2D();
    VecFloat2D v = VecFloatCreateStatic2D();
    VecSet(&p, 0, 0.0); VecSet(&p, 1, 0.0);

```

```

VecSet(&u, 0, 1.0); VecSet(&v, 1, 1.0);
ShapoidSetPos(facA, &p);
ShapoidSetAxis(facA, 0, &u);
ShapoidSetAxis(facA, 1, &v);
VecSet(&p, 0, 2.0); VecSet(&p, 1, 2.0);
VecSet(&u, 0, 0.5); VecSet(&v, 1, 0.5);
ShapoidSetPos(facB, &p);
ShapoidSetAxis(facB, 0, &u);
ShapoidSetAxis(facB, 1, &v);
if (FacoidAlignedIsInsideFacoidAligned(facA, facB) == true) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg,
        "FacoidAlignedIsInsideFacoidAligned failed");
    PBErrCatch(ShapoidErr);
}
VecSet(&p, 0, 0.1); VecSet(&p, 1, 0.1);
ShapoidSetPos(facB, &p);
if (FacoidAlignedIsInsideFacoidAligned(facB, facA) == false) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg,
        "FacoidAlignedIsInsideFacoidAligned failed");
    PBErrCatch(ShapoidErr);
}
VecSet(&u, 0, 1.0); VecSet(&v, 1, 1.0);
ShapoidSetAxis(facB, 0, &u);
ShapoidSetAxis(facB, 1, &v);
if (FacoidAlignedIsInsideFacoidAligned(facB, facA) == true) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg,
        "FacoidAlignedIsInsideFacoidAligned failed");
    PBErrCatch(ShapoidErr);
}
ShapoidFree(&facA);
ShapoidFree(&facB);
printf("UnitTestFacoidAlignedIsInsideFacoidAligned OK\n");
}

void UnitTestFacoidAlignedIsOutsideFacoidAligned() {
    Facoid* facA = FacoidCreate(2);
    Facoid* facB = FacoidCreate(2);
    VecFloat2D p = VecFloatCreateStatic2D();
    VecFloat2D u = VecFloatCreateStatic2D();
    VecFloat2D v = VecFloatCreateStatic2D();
    VecSet(&p, 0, 0.0); VecSet(&p, 1, 0.0);
    VecSet(&u, 0, 1.0); VecSet(&v, 1, 1.0);
    ShapoidSetPos(facA, &p);
    ShapoidSetAxis(facA, 0, &u);
    ShapoidSetAxis(facA, 1, &v);
    VecSet(&p, 0, 2.0); VecSet(&p, 1, 2.0);
    VecSet(&u, 0, 0.5); VecSet(&v, 1, 0.5);
    ShapoidSetPos(facB, &p);
    ShapoidSetAxis(facB, 0, &u);
    ShapoidSetAxis(facB, 1, &v);
    if (FacoidAlignedIsOutsideFacoidAligned(facA, facB) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg,
            "FacoidAlignedIsOutsideFacoidAligned failed");
        PBErrCatch(ShapoidErr);
    }
    VecSet(&p, 0, 0.1); VecSet(&p, 1, 0.1);
    ShapoidSetPos(facB, &p);
    if (FacoidAlignedIsOutsideFacoidAligned(facB, facA) == true) {

```

```

    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg,
        "FacoidAlignedIsOutsideFacoidAligned failed");
    PBErrCatch(ShapoidErr);
}
VecSet(&u, 0, 1.0); VecSet(&v, 1, 1.0);
ShapoidSetAxis(facB, 0, &u);
ShapoidSetAxis(facB, 1, &v);
if (FacoidAlignedIsOutsideFacoidAligned(facB, facA) == true) {
    ShapoidErr->_type = PBErrTypeUnitTestFailed;
    sprintf(ShapoidErr->_msg,
        "FacoidAlignedIsOutsideFacoidAligned failed");
    PBErrCatch(ShapoidErr);
}
ShapoidFree(&facA);
ShapoidFree(&facB);
printf("UnitTestFacoidAlignedIsOutsideFacoidAligned OK\n");
}

void UnitTestFacoidAlignedSplitExcludingFacoidAligned() {
    Facoid* facA = FacoidCreate(2);
    Facoid* facB = FacoidCreate(2);
    VecFloat2D p = VecFloatCreateStatic2D();
    VecFloat2D u = VecFloatCreateStatic2D();
    VecFloat2D v = VecFloatCreateStatic2D();
    VecSet(&p, 0, 0.0); VecSet(&p, 1, 0.0);
    VecSet(&u, 0, 1.0); VecSet(&v, 1, 1.0);
    ShapoidSetPos(facA, &p);
    ShapoidSetAxis(facA, 0, &u);
    ShapoidSetAxis(facA, 1, &v);
    VecSet(&p, 0, 0.5); VecSet(&p, 1, 0.5);
    VecSet(&u, 0, 1.0); VecSet(&v, 1, 1.0);
    ShapoidSetPos(facB, &p);
    ShapoidSetAxis(facB, 0, &u);
    ShapoidSetAxis(facB, 1, &v);
    GSet* split = FacoidAlignedSplitExcludingFacoidAligned(facA, facB);
    Facoid* facC = GSetPop(split);
    VecSet(&p, 0, 0.0); VecSet(&p, 1, 0.0);
    VecSet(&u, 0, 1.0); VecSet(&v, 1, 0.5);
    if (VecIsEqual(ShapoidPos(facC), &p) == false ||
        VecIsEqual(ShapoidAxis(facC, 0), &u) == false ||
        VecIsEqual(ShapoidAxis(facC, 1), &v) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg,
            "FacoidAlignedSplitExcludingFacoidAligned failed");
        PBErrCatch(ShapoidErr);
    }
    Facoid* facD = GSetPop(split);
    VecSet(&p, 0, 0.0); VecSet(&p, 1, 0.5);
    VecSet(&u, 0, 0.5); VecSet(&v, 1, 0.5);
    if (VecIsEqual(ShapoidPos(facD), &p) == false ||
        VecIsEqual(ShapoidAxis(facD, 0), &u) == false ||
        VecIsEqual(ShapoidAxis(facD, 1), &v) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg,
            "FacoidAlignedSplitExcludingFacoidAligned failed");
        PBErrCatch(ShapoidErr);
    }
    GSetFree(&split);
    ShapoidFree(&facA);
    ShapoidFree(&facB);
    ShapoidFree(&facC);
}

```

```

    ShapoidFree(&facD);
    printf("UnitTestFacoidAlignedSplitExcludingFacoidAligned OK\n");
}

void UnitTestFacoidAlignedAddClippedToSet() {
    Facoid* facA = FacoidCreate(2);
    VecFloat2D p = VecFloatCreateStatic2D();
    VecFloat2D u = VecFloatCreateStatic2D();
    VecFloat2D v = VecFloatCreateStatic2D();
    VecSet(&p, 0, 0.0); VecSet(&p, 1, 0.0);
    VecSet(&u, 0, 10.0); VecSet(&v, 1, 10.0);
    ShapoidSetPos(facA, &p);
    ShapoidSetAxis(facA, 0, &u);
    ShapoidSetAxis(facA, 1, &v);
    GSet set = GSetCreateStatic();
    FacoidAlignedAddClippedToSet(facA, &set);
    VecSet(&p, 0, 15.0); VecSet(&p, 1, 15.0);
    ShapoidSetPos(facA, &p);
    FacoidAlignedAddClippedToSet(facA, &set);
    VecSet(&p, 0, 8.0); VecSet(&p, 1, 8.0);
    ShapoidSetPos(facA, &p);
    FacoidAlignedAddClippedToSet(facA, &set);
    VecSet(&p, 0, 12.0); VecSet(&p, 1, 9.0);
    ShapoidSetPos(facA, &p);
    VecSet(&u, 0, 1.0); VecSet(&v, 1, 10.0);
    ShapoidSetAxis(facA, 0, &u);
    ShapoidSetAxis(facA, 1, &v);
    FacoidAlignedAddClippedToSet(facA, &set);
    VecSet(&p, 0, 5.0); VecSet(&p, 1, 5.0);
    ShapoidSetPos(facA, &p);
    VecSet(&u, 0, 1.0); VecSet(&v, 1, 1.0);
    ShapoidSetAxis(facA, 0, &u);
    ShapoidSetAxis(facA, 1, &v);
    FacoidAlignedAddClippedToSet(facA, &set);
    if (GSetNbElem(&set) != 6) {
        ShapoidErr->_type = PErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg,
            "FacoidAlignedAddClippedToSet failed");
        PErrCatch(ShapoidErr);
    }
    int iCheck = 0;
    float checkp[12] = {
        0.0, 0.0, 15.0, 15.0, 10.0, 8.0, 8.0,
        10.0, 8.0, 15.0, 12.0, 18.0};
    float checku[6] = {10.0, 10.0, 8.0, 10.0, 7.0, 1.0};
    float checkv[6] = {10.0, 10.0, 2.0, 5.0, 3.0, 1.0};
    do {
        Facoid* fac = GSetPop(&set);
        VecSet(&p, 0, checkp[2 * iCheck]);
        VecSet(&p, 1, checkp[2 * iCheck + 1]);
        VecSet(&u, 0, checku[iCheck]); VecSet(&v, 1, checkv[iCheck]);
        if (VecIsEqual(ShapoidPos(fac), &p) == false ||
            VecIsEqual(ShapoidAxis(fac, 0), &u) == false ||
            VecIsEqual(ShapoidAxis(fac, 1), &v) == false) {
            ShapoidErr->_type = PErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg,
                "FacoidAlignedAddClippedToSet failed");
            PErrCatch(ShapoidErr);
        }
        ShapoidFree(&fac);
        ++iCheck;
    } while(GSetNbElem(&set) > 0);
}

```

```

    ShapoidFree(&facA);
    printf("UnitTestFacoidAlignedAddClippedToSet OK\n");
}

void UnitTestShapoidIterCreateFree() {
    Facoid* facoid = FacoidCreate(2);
    VecFloat2D delta = VecFloatCreateStatic2D();
    ShapoidIter iter = ShapoidIterCreateStatic(facoid, &delta);
    if (iter._shap != (Shapoid*)facoid ||
        iter._pos == NULL ||
        iter._delta == NULL ||
        VecGetDim(iter._pos) != 2 ||
        VecGetDim(iter._delta) != 2) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIterFreeStatic failed");
        PBErrCatch(ShapoidErr);
    }
    ShapoidFree(&facoid);
    ShapoidIterFreeStatic(&iter);
    if (iter._pos != NULL ||
        iter._delta != NULL) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIterFreeStatic failed");
        PBErrCatch(ShapoidErr);
    }
    printf("UnitTestShapoidIterCreateFree OK\n");
}

void UnitTestShapoidIterGetSet() {
    Facoid* facoidA = FacoidCreate(2);
    Facoid* facoidB = FacoidCreate(2);
    VecFloat2D deltaA = VecFloatCreateStatic2D();
    VecFloat2D deltaB = VecFloatCreateStatic2D();
    for (int i = 2; i--;) {
        VecSet(&deltaA, i, 0.1);
        VecSet(&deltaB, i, 0.2);
    }
    ShapoidIter iter = ShapoidIterCreateStatic(facoidA, &deltaA);
    if (ShapoidIterShapoid(&iter) != (Shapoid*)facoidA) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIterShapoid failed");
        PBErrCatch(ShapoidErr);
    }
    if (VecIsEqual(ShapoidIterDelta(&iter), &deltaA) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIterDelta failed");
        PBErrCatch(ShapoidErr);
    }
    ShapoidIterSetShapoid(&iter, facoidB);
    ShapoidIterSetDelta(&iter, &deltaB);
    if (ShapoidIterShapoid(&iter) != (Shapoid*)facoidB) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIterSetShapoid failed");
        PBErrCatch(ShapoidErr);
    }
    if (VecIsEqual(ShapoidIterDelta(&iter), &deltaB) == false) {
        ShapoidErr->_type = PBErrTypeUnitTestFailed;
        sprintf(ShapoidErr->_msg, "ShapoidIterSetDelta failed");
        PBErrCatch(ShapoidErr);
    }
    ShapoidFree(&facoidA);
}

```

```

    ShapoidFree(&facoidB);
    ShapoidIterFreeStatic(&iter);
    printf("UnitTestShapoidIterGetSet OK\n");
}

void UnitTestShapoidIterStepFacoid() {
    Facoid* facoid = FacoidCreate(2);
    VecFloat2D delta = VecFloatCreateStatic2D();
    for (int i = 2; i--;)
        VecSet(&delta, i, 0.25);
    ShapoidIter iter = ShapoidIterCreateStatic(facoid, &delta);
    int iCheck = 0;
    float check[50] = {0.000,0.000,0.000,0.250,0.000,0.500,0.000,0.750,
        0.000,1.000,0.250,0.000,0.250,0.250,0.250,0.500,0.250,0.750,0.250,
        1.000,0.500,0.000,0.500,0.250,0.500,0.500,0.500,0.750,0.500,1.000,
        0.750,0.000,0.750,0.250,0.750,0.500,0.750,0.750,0.750,1.000,1.000,
        0.000,1.000,0.250,1.000,0.500,1.000,0.750,1.000,1.000
    };
    do {
        VecFloat* v = ShapoidIterGetInternal(&iter);
        if (ISEQUALF(VecGet(v, 0), check[2 * iCheck]) == false ||
            ISEQUALF(VecGet(v, 1), check[2 * iCheck + 1]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidIterStep failed");
            PBErrCatch(ShapoidErr);
        }
        VecFree(&v);
        ++iCheck;
    } while (ShapoidIterStep(&iter));
    ShapoidFree(&facoid);
    ShapoidIterFreeStatic(&iter);
    printf("UnitTestShapoidIterStepFacoid OK\n");
}

void UnitTestShapoidIterStepPyramidoid() {
    Pyramidoid* pyramidoid = PyramidoidCreate(3);
    VecFloat3D delta = VecFloatCreateStatic3D();
    for (int i = 3; i--;)
        VecSet(&delta, i, 0.25);
    ShapoidIter iter = ShapoidIterCreateStatic(pyramidoid, &delta);
    int iCheck = 0;
    float check[105] = {0.000,0.000,0.000,0.000,0.000,0.250,0.000,0.000,
        0.500,0.000,0.000,0.750,0.000,0.000,1.000,0.000,0.250,0.000,0.000,
        0.250,0.250,0.000,0.250,0.500,0.000,0.250,0.750,0.000,0.500,0.000,
        0.000,0.500,0.250,0.000,0.500,0.500,0.000,0.750,0.000,0.000,0.750,
        0.250,0.000,1.000,0.000,0.250,0.000,0.000,0.250,0.000,0.250,0.250,
        0.000,0.500,0.250,0.000,0.750,0.250,0.250,0.000,0.250,0.250,0.250,
        0.250,0.250,0.500,0.250,0.500,0.000,0.250,0.500,0.250,0.250,0.750,
        0.000,0.500,0.000,0.000,0.500,0.000,0.250,0.500,0.000,0.500,0.500,
        0.250,0.000,0.500,0.250,0.250,0.500,0.500,0.000,0.750,0.000,0.000,
        0.750,0.000,0.250,0.750,0.250,0.000,1.000,0.000,0.000
    };
    do {
        VecFloat* v = ShapoidIterGetInternal(&iter);
        if (ISEQUALF(VecGet(v, 0), check[3 * iCheck]) == false ||
            ISEQUALF(VecGet(v, 1), check[3 * iCheck + 1]) == false ||
            ISEQUALF(VecGet(v, 2), check[3 * iCheck + 2]) == false) {
            ShapoidErr->_type = PBErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidIterStep failed");
            PBErrCatch(ShapoidErr);
        }
        VecFree(&v);
    }
}

```

```

        ++iCheck;
    } while (ShapoidIterStep(&iter));
    ShapoidFree(&pyramidoid);
    ShapoidIterFreeStatic(&iter);
    printf("UnitTestShapoidIterStepPyramidoid OK\n");
}

void UnitTestShapoidIterStepSpheroid() {
    int dim = 3;
    Spheroid* spheroid = SpheroidCreate(dim);
    VecFloat* delta = VecFloatCreate(dim);
    for (int i = dim; i--;)
        VecSet(delta, i, 0.25);
    ShapoidIter iter = ShapoidIterCreateStatic(spheroid, delta);
    int iCheck = 0;
    float check[147] = {
        0.00000,0.00000,-0.50000,0.00000,-0.43301,-0.25000,-0.39244,
        -0.18301,-0.25000,-0.14244,-0.18301,-0.25000,0.10756,-0.18301,
        -0.25000,0.35756,-0.18301,-0.25000,0.39244,-0.18301,-0.25000,
        -0.42780,0.06699,-0.25000,-0.17780,0.06699,-0.25000,0.07220,
        0.06699,-0.25000,0.32220,0.06699,-0.25000,0.42780,0.06699,
        -0.25000,-0.29499,0.31699,-0.25000,-0.04499,0.31699,-0.25000,
        0.20501,0.31699,-0.25000,0.29499,0.31699,-0.25000,0.00000,
        -0.50000,0.00000,-0.43301,-0.25000,0.00000,-0.18301,-0.25000,
        0.00000,0.06699,-0.25000,0.00000,0.31699,-0.25000,0.00000,0.43301,
        -0.25000,0.00000,-0.50000,0.00000,0.00000,-0.25000,0.00000,0.00000,
        0.00000,0.00000,0.00000,0.25000,0.00000,0.00000,0.50000,0.00000,
        0.00000,-0.43301,0.25000,0.00000,-0.18301,0.25000,0.00000,0.06699,
        0.25000,0.00000,0.31699,0.25000,0.00000,0.43301,0.25000,0.00000,
        0.00000,0.50000,0.00000,0.00000,-0.43301,0.25000,-0.39244,-0.18301,
        0.25000,-0.14244,-0.18301,0.25000,0.10756,-0.18301,0.25000,0.35756,
        -0.18301,0.25000,0.39244,-0.18301,0.25000,-0.42780,0.06699,0.25000,
        -0.17780,0.06699,0.25000,0.07220,0.06699,0.25000,0.32220,0.06699,
        0.25000,0.42780,0.06699,0.25000,-0.29499,0.31699,0.25000,-0.04499,
        0.31699,0.25000,0.20501,0.31699,0.25000,0.29499,0.31699,0.25000,
        0.00000,0.00000,0.50000
    };
    do {
        VecFloat* v = ShapoidIterGetInternal(&iter);
        if (ISEQUALF(VecGet(v, 0), check[3 * iCheck]) == false ||
            ISEQUALF(VecGet(v, 1), check[3 * iCheck + 1]) == false ||
            ISEQUALF(VecGet(v, 2), check[3 * iCheck + 2]) == false) {
            ShapoidErr->_type = PErrTypeUnitTestFailed;
            sprintf(ShapoidErr->_msg, "ShapoidIterStep failed");
            PErrCatch(ShapoidErr);
        }
        VecFree(&v);
        ++iCheck;
    } while (ShapoidIterStep(&iter));
    ShapoidFree(&spheroid);
    ShapoidIterFreeStatic(&iter);
    VecFree(&delta);
    printf("UnitTestShapoidIterStepSpheroid OK\n");
}

void UnitTestShapoidIter() {
    UnitTestShapoidIterCreateFree();
    UnitTestShapoidIterGetSet();
    UnitTestShapoidIterStepFacoid();
    UnitTestShapoidIterStepPyramidoid();
    UnitTestShapoidIterStepSpheroid();
}

```

```

    printf("UnitTestShapoidIter OK\n");
}

void UnitTestAll() {
    UnitTestCreateCloneIsEqualFree();
    UnitTestLoadSavePrint();
    UnitTestGetSetTypeDimPosAxis();
    UnitTestTranslateScaleGrow();
    UnitTestRotate();
    UnitTestRotateAxis();
    UnitTestRotateX();
    UnitTestRotateY();
    UnitTestRotateZ();
    UnitTestImportExportCoordIsPosInside();
    UnitTestGetBoundingBox();
    UnitTestGetPosDepthCenterCoverage();
    UnitTestFacoidAlignedIsInsideFacoidAligned();
    UnitTestFacoidAlignedIsOutsideFacoidAligned();
    UnitTestFacoidAlignedSplitExcludingFacoidAligned();
    UnitTestFacoidAlignedAddClippedToSet();
    UnitTestShapoidIter();
    printf("UnitTestAll OK\n");
}

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

```

6 Unit tests output

```

UnitTestCreateCloneIsEqualFree OK
Type: Facoid
Dim: 3
Pos: <0.000,0.000,0.000>
Axis(0): <1.000,0.000,0.000>
Axis(1): <0.000,1.000,0.000>
Axis(2): <0.000,0.000,1.000>
UnitTestLoadSavePrint OK
UnitTestGetSetTypeDimPosAxis OK
UnitTestTranslateScaleGrow OK
UnitTestRotate OK
UnitTestRotateAxis OK
UnitTestRotateX OK
UnitTestRotateY OK
UnitTestRotateZ OK
UnitTestImportExportCoordIsPosInside OK
UnitTestGetBoundingBox OK
UnitTestGetPosDepthCenterCoverage OK
UnitTestFacoidAlignedIsInsideFacoidAligned OK
UnitTestFacoidAlignedIsOutsideFacoidAligned OK
UnitTestFacoidAlignedSplitExcludingFacoidAligned OK
UnitTestFacoidAlignedAddClippedToSet OK
UnitTestShapoidIterCreateFree OK
UnitTestShapoidIterGetSet OK
UnitTestShapoidIterStepFacoid OK
UnitTestShapoidIterStepPyramidoid OK

```



```
UnitTestShapoidIterStepSpheroid OK
UnitTestShapoidIter OK
UnitTestAll OK
```

facoid.txt

```
3 0
3 0.000000 0.000000 0.000000
3 1.000000 0.000000 0.000000
3 0.000000 1.000000 0.000000
3 0.000000 0.000000 1.000000
```

Example of path on a 2D Spheroid using the ShapoidIterator:

