The EGADS API

Engineering Geometry Aircraft Design System

at ESP Revision 1.29

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Part of the Engineering Sketch Pad (ESP)

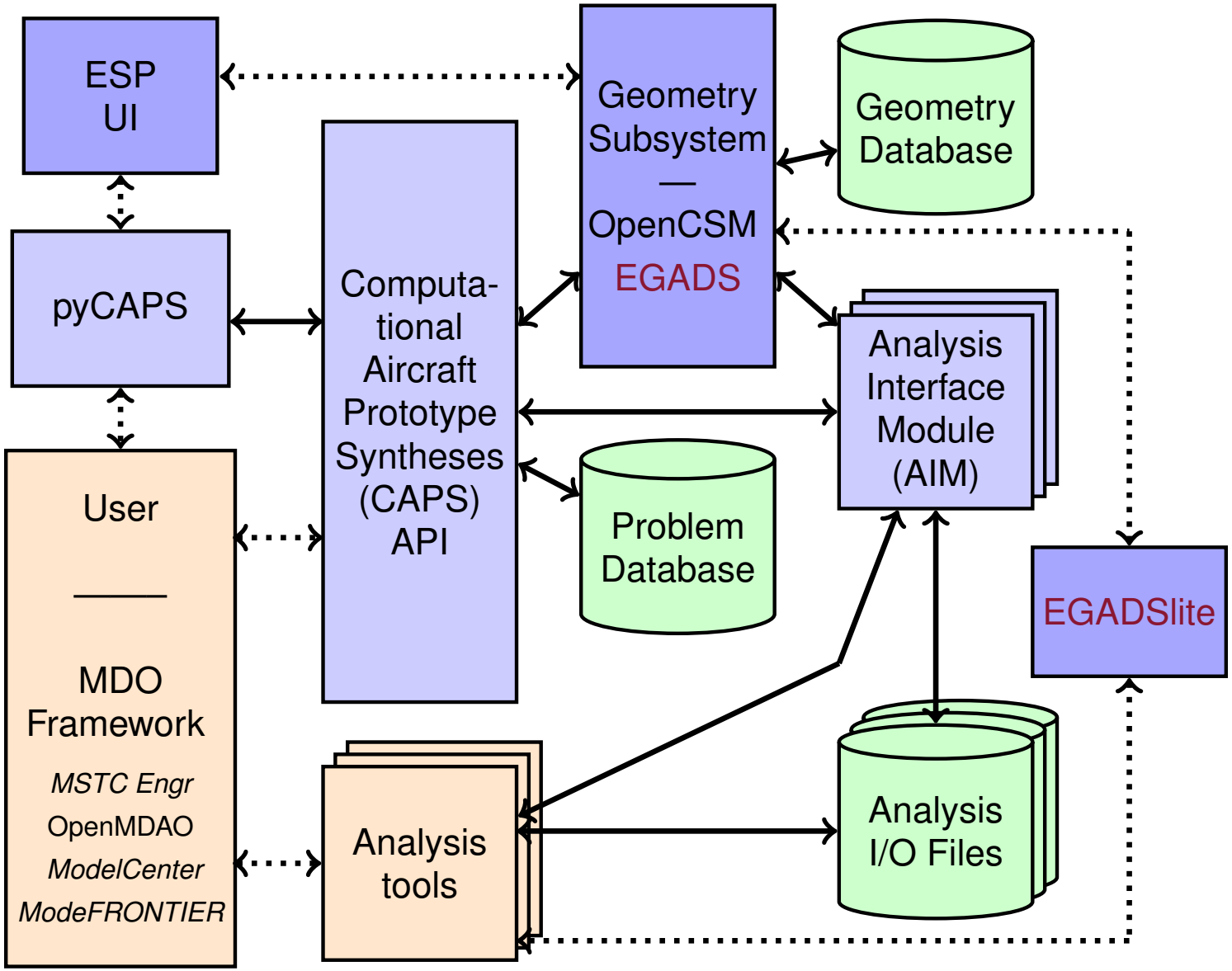


Table of Contents

Overview

Provide a "bottom up" and/or Constructive Solid Geometry foundation for building Aircraft (or other mechanical devices)

- Built upon OpenCASCADE
  - Open Source solid modeling geometry kernel
  - Support for manifold and non-manifold geometry
  - Reading & writing IGES, STEP and native formats
  - C++ with ~17,000 methods!
- Open Source (LGPL v2.1)
- C/C++, FORTRAN, Python and Julia Interfaces
  - Single API with minor variations for FORTRAN
  - Always returns an integer code (success/error condition)
  - Requires C pointer access in FORTRAN
    - Cray-pointer construct –or–
    - C-pointers (2003 extension to FORTRAN 90)
    - Both supported by Intel FORTRAN and gfortran
    - API contains memory functions

Overview

System Support

- **macOS** with clang, ifort and/or gfortran
- **LINUX** with gcc, ifort and/or gfortran
- **Windows** with Microsoft Visual Studio C++ and ifort
- No global variables and thread-safe
- Various levels of verbose output (0-none, through 3-debug)
- Written in C and C++
- Fortran bindings written in C
- `pyEGADS` requires no other dependencies other than a current version of Python
- `jlEGADS` requires Julia *v*1.6 or greater

Overview

EGADS Objects

- Treated as "blind" pointers – an ego
  - Allows for an *Object-based* programming model
  - Can access internals in C/C++
- Context Object holds *global* information
- egos have:
  - *Owner*: Context, Body, EBody, or Model
  - Reference Objects (objects they depend upon)
- egos are INTEGER*8 variables in FORTRAN
  - Allows for same source code regardless of size of pointer
  - Requires "freeing" of internal lists of objects (not for C/C++)

Overview

The Context Object and Threads

- When a Context Object is created (`EG_open` – page 51) the calling thread ID is saved within the Context
- Any construction functions or functions that change the attribute storage must be done from the thread stored in the Context
- The Context's thread may be modified by invoking `EG_updateThread` (page 56) called from the new thread

MultiThreading

- After a thread is spawned, it can call `EG_open` (page 51) to setup a Context to use with the thread
  - Will work with native threads, `ESP`'s `EMP` package or *OpenMP*
- Use `EG_copyObject` (page 58) to copy an object from its owning Context to the target Context specified in the 2nd argument
- Use `EG_contextCopy` (page 59) to copy an object to the target Context specified by the 1st argument

See `$ESP_ROOT/src/EGADS/examples/multiContext.c` for an example using `EMP`

Overview

EGADSlite – for HPC Environments

- No construction supported
- Same API and Object model as EGADS
  - Can use EGADS to prototype/build EGADSlite code
- Suitable for MPI
  - From EGADS via a *stream*, see EG_exportModel – page 62
  - To EGADSlite from the *stream*, see EG_importModel – page 62
  - *Stream* setup to Broadcast (or write to disk)
- ANSI C – No OpenCASCADE
- Tiny memory footprint
- Thread safe and scalable
  - EGADS' OpenCASCADE evaluation functions replaced with those written for EGADSlite

See $ESP_ROOT/externApps/Pagoda/EGADSserver for an MPI example

EGADS Objects

- Context – Holds the *globals*
- Transform
- Tessellation
- Nil (allocated but not assigned) – internal
- Empty – internal
- Reference – internal
- Geometry
  - pcurve, curve, surface
- Topology
  - Node, Edge, Loop, Face, Shell, Body, Model
- *Effective Topology*
  - EEdge, ELoop, EFace, EShell, EBody

See `$ESP_ROOT/include/egadsTypes.h` for a list of `defines`

EGADS Objects

C structure definition - an ego

```
typedef struct egObject {
   int    magicnumber;          /* must be properly set to validate
                                   the object */
   short  oclass;               /* object class */
   short  mtype;                /* object member type */
   void   *attrs;               /* attributes or reference */
   void   *blind;               /* blind pointer to OpenCASCADE or
                                   EGADS data */
   struct egObject *topObj;     /* top of the hierarchy or
                                   context (if top) */
   struct egObject *ref;        /* threaded list of references */
   struct egObject *prev;       /* back pointer */
   struct egObject *next;       /* forward pointer */
 } egObject;
#define ego egObject*;
```

Context Object

- Start of dual threaded-list of active egos
- Pool of deleted objects

EGADS Objects – Attribution

Attribution Modes

- Single [default] – One attribute on an Object can have the **name**
- Full – There can be any number of attributes with the same **name**

Attributes

- Are identified by a **name** (character string with no spaces or other special characters)
- Each attribute has a single **type**:
  - Integer
  - Real (double precision)
  - String (can have spaces and other special characters)
  - CSys – Coordinate System (uses the Real storage)
  - Ptr – Supplied pointer (not persistent and the programmer is responsible for memory management, i.e. freeing the storage). Uses the String pointer.
- And a **length** (for Integer, Real and CSys types)

EGADS Objects – Attribution

Objects & Attributes

- Any Object (except for Reference) may have multiple Attributes
- Only Attributes on Topological Objects are copied (except for Pointers)
- Only Attributes on Topological, *Effective* and Tessellation Objects are persistent (except for Pointer Types) – and this is available only through ".egads" file IO.

SBOs and Intersection Functions

- Attributes on Faces will be carried through to the resultant fragments after intersections (except for Pointer types)
- Unmodified Topology maintains their attributes (except for Pointers)

EGADS Objects – Attribution

More Complex Associations

From `EG_filletBody`, `EG_chamferBody` and `EG_hollowBody` a list is returned containing an *operation* and an index to a source object in the Body:

operation	Description
NODEOFF (1)	The Face is the result of a Node – the index is that of the Node in the source Body
EDGEOFF (2)	The Face is the result of an Edge – the index is the Edge index (see `EG_indexBodyTopo`, page 97)
FACEDUP* (3)	The Face is an exact copy of the source
FACECUT* (4)	The Face has been trimmed or split from the source
FACEOFF (5)	The Face is offset from the source Face – the index is that of the source

* Note: this information is redundant with the use of Face attribution

EGADS Objects – Attribution

Coordinate Systems – ATTRCSYS

- Input Reals must be one of:
  - Any Object may have 9 values
    - position†, first direction†, second direction†
  - FACE/SURFACE can also have 6 or 3 values
    - u, v, flip, second direction† (first direction is flip*normal)
    - u, v, *idir*: 1 – udir, 2 – vdir, 3 – -udir, 4 – -vdir
      first direction is the normal, second is set by *idir*
      if *idir* is negated then the normal direction is flipped
  - EDGE/CURVE can have 5 values
    - t, flip, second direction† (first direction is flip*tangent)
  - NODE can have 6 values
    - first direction†, second direction†
- Output is the position and 3 orthonormal directions
  - 12 doubles returned after the input values or `egads.csystem.ortho[4][3]` for `EG_attributeGet` (page 67) and `EG_attributeRet` (page 66)

Notes:

1. third direction is implied by first × second
2. † transformed when object has been transformed
3. The actual number of doubles is the attribute length above + 12

EGADS Objects – Attribution

Full Attribution – not the default mode

1. Edge and Node attributes are tracked through EGADS operations.
2. Multiple attributes with the same **name** are maintained. This did not matter in the default scheme because rarely did Faces have this issue, and when it did happen, the attributes from the "tool" of SBOs were used.
3. To track multiple (same **name**) attributes attached to an object with different values, a sequence number is internally added to the **name**. In the past the **name** of the attribute could not have spaces, so a space is used as the delimiter.
4. When merging attributes with the same **name**:
   a) If there is only a single attribute with the **name** and the value on the proposed merged attribute is the same then there is no merge/addition.
   b) If the values are different, then the **name** of the existing attribute is appended with " 1" and the **name** of the added attribute is appended the sequence number " 2". That is, an attribute **name** without a sequence number can only exist with a single attribute of that **name**.
   c) If there are already multiple sequences for the same **name**, any additional merges adds the attribute and bumps the sequence –unless–
   d) Any attribute merge that has the same value as an existing attribute (of the same **name**) will not be added. This is consistent with (4a) above for the single (non sequenced) attribute.
5. Sequence numbers always start with 1 and go to the number of attributes sharing that **name**. You will not find a single attribute with a sequence number (the sequence number extension will be removed by EGADS).

EGADS Geometry Objects

oclass = PCURVE – Parameter Space Curves

- 2D curves in the Parametric space $[u, v]$ of a surface
- Types: Line, Circle, Ellipse, Parabola, Hyperbola, Trimmed, Bezier, BSpline, Offset
- All types abstracted to $[u, v] = g(t)$

oclass = CURVE

- 3D curve – single running parameter (t)
- Types: Line, Circle, Ellipse, Parabola, Hyperbola, Trimmed, Bezier, BSpline, Offset
- All member types abstracted to $[x, y, z] = g(t)$

EGADS Geometry Objects

oclass = SURFACE

- 3D surfaces of 2 parameters $[u, v]$
- Types: Plane, Spherical, Cylindrical, Revolution, Toriodal, Trimmed, Bezier, BSpline, Offset, Conical, Extrusion
- All types abstracted to $[x, y, z] = f(u, v)$

Detailed Geometry

- Geometry is created by invoking `EG_makeGeometry` (page 73)
- Geometry is queried via calls to `EG_getGeometry` (page 74)
- The information is always a pointer to doubles with an optional pointer to ints – the lengths required are described below
- Some member types require an ego as a reference
- Analytic derivatives exist for many Geometry functions – see `$ESP_ROOT/doc/EGADS/EGADS_dot/EGADS_dot.pdf`

EGADS Geometry – PCURVE / CURVE

mtype = LINE

data length ⇒	PCurve – 4	Curve – 6
Location	$[u, v]$	$[x, y, z]$
Direction	$[dir_u, dir_v]$	$[dir_x, dir_y, dir_z]$

mtype = CIRCLE

data length ⇒	PCurve – 7	Curve – 10
Center	$[u, v]$	$[x, y, z]$
Xaxis	$[xax_u, xax_v]$	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_u, yax_v]$	$[yax_x, yax_y, yax_z]$
Radius		

note: Xaxis and Yaxis should be orthogonal

EGADS Geometry – PCURVE / CURVE

mtype = ELLIPSE

data length ⇒	PCurve – 8	Curve – 11
Location	$[u, v]$	$[x, y, z]$
Xaxis	$[xax_u, xax_v]$	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_u, yax_v]$	$[yax_x, yax_y, yax_z]$
MajorRadius		
MinorRadius		

note: Xaxis and Yaxis should be orthogonal

mtype = PARABOLA

data length ⇒	PCurve – 7	Curve – 10
Location	$[u, v]$	$[x, y, z]$
Xaxis	$[xax_u, xax_v]$	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_u, yax_v]$	$[yax_x, yax_y, yax_z]$
Focus		

note: Xaxis and Yaxis should be orthogonal

EGADS Geometry – PCURVE / CURVE

mtype = HYPERBOLA

data length ⇒	PCurve – 8	Curve – 11
Location	$[u, v]$	$[x, y, z]$
Xaxis	$[xax_u, xax_v]$	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_u, yax_v]$	$[yax_x, yax_y, yax_z]$
MajorRadius		
MinorRadius		

note: Xaxis and Yaxis should be orthogonal

mtype = TRIMMED

data length ⇒	PCurve – 2	Curve – 2
Range	t-start, t-end	t-start, t-end

note: Requires reference geometry of same class (PCURVE or CURVE)

EGADS Geometry – PCURVE / CURVE

mtype = OFFSET

data length ⇒	PCurve – 1	Curve – 4
Direction	—	$[dir_x, dir_y, dir_z]$
Offset		

note: Requires reference geometry of same class (PCURVE or CURVE)

mtype = BEZIER

int [3]	Description
Bit Flag	2 – rational, 4 – periodic
Degree	nCP-1 up to 25 (not used on input)
nCP	number of control points

doubles	PCurve	Curve
Control Points	2*nCP	3*nCP
Weights*	nCP	nCP

* note: Weights exist only if rational

EGADS Geometry – PCURVE / CURVE

mtype = BSPLINE (includes NURBS)

int [4]	Description
Bit Flag	2 – rational, 4 – periodic
Degree	
nCP	number of control points
nKnots	number of knots

doubles	PCurve	Curve
Knots	nKnots	nKnots
Control Points	2*nCP	3*nCP
Weights*	nCP	nCP

* note: Weights exist only if rational

EGADS Geometry – SURFACE

mtype = PLANE

data length ⇒	9
Location	$[x, y, z]$
Xaxis	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_x, yax_y, yax_z]$

note: Xaxis and Yaxis should be orthogonal

mtype = SPHERICAL

data length ⇒	10
Center	$[x, y, z]$
Xaxis	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_x, yax_y, yax_z]$
Radius	

notes:

1. Xaxis and Yaxis should be orthogonal
2. negative Radius indicates a left-handed coordinate system

EGADS Geometry – SURFACE

mtype = CONICAL

data length ⇒	14
Location	$[x, y, z]$
Xaxis	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_x, yax_y, yax_z]$
Zaxis	$[zax_x, zax_y, zax_z]$
Angle	
Radius	

notes:

1. Xaxis and Yaxis and Zaxis should all be orthogonal
2. Zaxis is the rotation axis and may be left-handed
3. Angle is in radians from 0 to $\pi/2$

EGADS Geometry – SURFACE

mtype = CYLINDRICAL

data length ⇒	13
Location	$[x, y, z]$
Xaxis	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_x, yax_y, yax_z]$
Zaxis	$[zax_x, zax_y, zax_z]$
Radius	

notes:

1. Xaxis and Yaxis and Zaxis should all be orthogonal
2. Zaxis is the rotation axis and may be left-handed

mtype = EXTRUSION

data length ⇒	3
Direction	$[dir_x, dir_y, dir_z]$

note: requires reference geometry of class CURVE

EGADS Geometry – SURFACE

mtype = TOROIDAL

data length ⇒	14
Center	$[x, y, z]$
Xaxis	$[xax_x, xax_y, xax_z]$
Yaxis	$[yax_x, yax_y, yax_z]$
Zaxis	$[zax_x, zax_y, zax_z]$
MajorRadius	
MinorRadius	

notes:

1. Xaxis and Yaxis and Zaxis should all be orthogonal
2. Zaxis is the rotation axis and may be left-handed

mtype = REVOLUTION

data length ⇒	6
Center	$[x, y, z]$
Axis	$[axi_x, axi_y, axi_z]$

note: requires reference geometry of class CURVE

EGADS Geometry – SURFACE

mtype = TRIMMED

data length ⇒	4
uRange	$[u_{min}, u_{max}]$
vRange	$[v_{min}, v_{max}]$

note: requires reference geometry of class SURFACE

mtype = OFFSET

data length ⇒	1
distance	

notes:

1. requires reference geometry of class SURFACE
2. Offset distance is applied normal to the reference

EGADS Geometry – SURFACE

mtype = BEZIER

int [5]	Description
Bit Flag	2 – rational, 4 – uPeriodic , 8 – vPeriodic
uDegree	nCPu-1 up to 25 (not used on input)
nCPu	number of control points in the *u* direction
vDegree	nCPv-1 up to 25 (not used on input)
nCPv	number of control points in the *v* direction

doubles	packed data
Control Points	3*nCPu*nCPv
Weights*	nCPu*nCPv

* note: Weights exist only if rational

EGADS Geometry – SURFACE

mtype = BSPLINE (includes NURBS)

int [7]	Description
Bit Flag	2 – rational, 4 – uPeriodic , 8 – vPeriodic
uDegree	the degree of the BSpline in the u direction
nCPu	number of control points in u
nUKnots	number of knots in u
vDegree	the degree of the BSpline in the v direction
nCPv	number of control points in v
nVKnots	number of knots in v

doubles	packed data
uKnots	
vKnots	
Control Points	3*nCPu*nCPv
Weights*	nCPu*nCPv

* note: Weights exist only if rational

Boundary Representation – BRep

Top Down ↓ ↑ *Bottom Up*

Topological Entity	Geometric Entity	Function
Model		
Body	Solid, Sheet, Wire	
Shell		
Face	**surface**	$(x, y, z) = \mathbf{f}(u, v)$
Loop	**pcurves***	
Edge	**curve**	$(x, y, z) = \mathbf{g}(t)$
Node	**point**	

- Nodes that bound Edges may not be on underlying curves
- Edges in the Loops that trim a Face may not sit on the surface hence the use of pcurves
- * Loops may be geometry free or have associated pcurves (one for each Edge) and the surface where the pcurves reside

See `$ESP_ROOT/doc/Concepts.pdf` for a pictorial view of EGADS Topology

EGADS Topology Objects

Node

- Contains a point – $[x, y, z]$
- Member Types: **none**

Edge

- Has a 3D curve (if not DEGENERATE)
- Has a t range (t_{min} to t_{max}, where $t_{min} < t_{max}$)
  Note: The positive orientation is going from t_{min} to t_{max}
- Has a Node for t_{min} and for t_{max} – can be the same Node
- Member Types:
  - ONENODE – periodic
  - TWONODE – a normal Edge
  - DEGENERATE – single Node
    marks a collapsed u or v on a SURFACE
    t range specifies the limits used for the pcurve (in the Loop)

EGADS Topology Objects – Loops

Loop – without a reference surface

1. Free standing connected Edges
   See page 36 for parsing a non-manifold WireBody
2. A list of connected Edges associated with a Plane (which does not require pcurves)

- An ordered collection of Edge objects with associated senses that define the connected Loop
- Segregates space by maintaining material to the left of the running Loop (or traversed right-handed pointing out of the intended volume)
- No Edges should be Degenerate
- Member Types: OPEN or CLOSED (comes back on itself)

EGADS Topology Objects – Loops

Loop – with a reference surface

1. Collections of Edges (like Loops without a surface) followed by a corresponding collection of pcurves that define the $[u, v]$ trimming on the surface
   - Degenerate Edges are required when the $[u, v]$ mapping collapses like at the apex of a cone (note that the pcurve is needed to be fully defined using the Edge's t range)
   - An Edge may be found in a Loop twice (with opposite senses) and with different pcurves. For example a closed cylindrical surface at the seam – one pcurve would represent the beginning of the period where the other is the end of the periodic range.
   - Types: OPEN or CLOSED (comes back on itself)

EGADS Topology Objects – Face

Face

- A surface bounded by one or more Loops with associated senses
- Only one outer Loop (sense = SOUTER(1)) and any number of inner Loops (sense = SINNER(-1)). Note that under very rare conditions a Loop may be found in more than 1 Face – in this case the one marked with sense = +/- 2 must be used in a reverse manner.
- All Loops must be CLOSED
- Loop(s) must not contain reference geometry for Planar surfaces
- If the surface is not a Plane then the Loop's reference Object must match that of the Face
- `mtype` is the orientation of the Face based on surface's $U \otimes V$:
  - SFORWARD or SREVERSE when the orientations are opposed

Note that this is coupled with the Loop's orientation (i.e. an outer Loop traverses the Face in a right-handed manner defining the outward direction)

EGADS Topology Objects

Shell

- A collection of one or more connected Faces that if CLOSED segregates regions of 3-Space
- All Faces must be properly oriented
- Non-manifold Shells can have more than 2 Faces sharing an Edge
- Member Types: OPEN (including non-manifold) or CLOSED
- CLOSED Shells are required for SOLIDBODY Body types

EGADS Topology Objects

Body

- Container used to aggregate Topology
- *Owns* all the Objects contained within
- Member Types:
  - WIREBODY – contains a single Loop
    call `EG_getBodyTopos` on Edges and compare to the number of Edges in the Loop
    if different → non-manifold therefore use the Edges returned from `EG_getBodyTopos`
  - FACEBODY – contains a single Face – IGES import
  - SHEETBODY – contains one or more Shell(s) which can be either non-manifold or manifold (though usually a manifold Body of this type is promoted to a SOLIDBODY)
  - SOLIDBODY:
    - A manifold collection of one or more CLOSED Shells with associated senses
    - There may be only one outer Shell (sense = SOUTER(1)) and any number of inner Shells (sense = SINNER(-1))
    - Edges (except DEGENERATE) found exactly twice (sense = ± 1)

EGADS *Effective Topology*

Topology	**BRep** define	**Effective** define	**Note**
Model			Container for Bodies, EBodies & Tessellations
Body	BODY	EBODY	An EBody is a modification of a Body w/ "E" entities
Shell	SHELL	ESHELL	1 to 1 mapping
Face	FACE	EFACE	EFace consists of 1 or more Faces
Loop	LOOP	ELOOPX	Collection of EEdges, No pcurves
Edge	EDGE	EEDGE	EEdge consists of 1 or more ordered Edges
Node	NODE	n/a	no ENodes, but not all Nodes in the Body are found in the EBody

Virtual Topology & BRep closure

- BRep Topology can inhibit *quality* meshes
  - Spurious Nodes
  - Small Edges that could be coalesced
  - Sliver Faces
- EGADS' *Effective Topology*
  - Automatically removes spurious Nodes (unless the Node has `.Keep` attribute)
  - Automatically coalesces Edges (unless the Edge has `.Keep` attribute) to make EEdges
  - Collects Faces explicitly or by attribute
    uses a global $[u, v]$ mapping driven by an EGADS tessellation
    Face triangulations must *touch* along at least 1 triangle side
  - EFaces & EEdges contain no geometry, therefore depend on the included BRep Objects
  - Adjusts EFace & EEdge inverse and forward evaluations based on closure at bounds

EGADS *Effective Topology* Objects

- *Effective Topology* Objects can maintain their own attributes
- EBody Objects can have their own tessellations.
- *Effective Topology* Objects can NOT be used in construction.
- Nodes that have Degenerate Edges cannot disappear from the EBody. This also means that certain collections of Faces will not be allowed that may remove all Edges supporting that Node.
- EFaces (of more than 1 Face) are always SFORWARD
- The direction of the EEdge is set by the first Edge in the collection. This means that a positive direction is based on the connecting Node to the next Edge, which may have the first Edge traversed in the negative sense.
- The rules for collecting entities in Solid Bodies differ from those of Sheet Bodies where Edges are exposed (only trimming a single Face). In this case an angle criteria is used when making EEdges and removing Nodes.
- A Face my be evaluated throughout the *UVbox* range. This is not true for EFaces containing more than a single Face. An evaluation is only valid based on the original input tessellation.

Discrete representation of an Object

Geometry

- Unconnected discretization of the range of the Object
  - Polyline for curves at constant t increments
  - Regular grid for surfaces at constant increments (isoclines)

Body/EBody Topology

- Connected and trimmed tessellation including:
  - Polyline for Edges/EEdges
  - Triangulation for Faces/EFaces
  - Optional Quadrilateral Patching for Faces/EFaces
- Ownership and Geometric Parameters for Vertices
- Adjustable parameters for side length and curvature (x2)
- Watertight
- Exposed per Face/Edge or Global indexing

EGADS Objects – Tessellation

Control of the use of Quadrilateral Templates

- Automatic with triangulation scheme
- Attempts to isolate 3 or 4 "sides"
  - Only single Loop/ELoop
  - Faces/EFaces with more than 4 Edges/EEdges are analyzed to see is multiple EDGEs can be treated as a single "side"
- Point counts on sides (based on Edge/EEdge Tessellation):
  - TFI if opposites are equal
  - Templates otherwise
- Defeated/modified with Body/EBody or Face/EFace attribute `.qParams`
  - If ATTRSTRING – turn off quadding templates
  - If ATTRREAL (3 in length):
    1. Edge/EEdge matching expressed as the deviation from alignment [default: 0.05]
    2. Maximum quad side ratio point count to allow [default: 3.0]
    3. Number of smoothing iterations [default: 0.0]

EGADS Objects – Tessellation

Manual Watertight Quadrilateral Face/EFace Treatment

- Requires Existing Body/EBody Tessellation
- Must be able to Isolate 4 "sides"
  - Only single Loops/ELoops
  - Faces/EFaces with more than 4 Edges/EEdges are analyzed to see is multiple Edges/EEdges can be treated as a single "side"
  - No DEGENERATE Edges/EEdges
- Point counts on sides (based on Edge/EEdgeTessellation):
  - TFI if opposites are equal
  - Templates otherwise
- Can use Edge Tessellation Adjustment Functions when point counts don't allow for Quadding
- See the function `EG_makeQuads` – page 123.

EGADS Objects – Tessellation

Body/EBody Watertight Full Quadrilateral Treatment

- Fully automatic & robust
- Method:
  1. Starts from an EGADS triangulation of a Body (Tessellation Object)
  2. Subdivides all triangle sides so that each triangle becomes 3 quadrilaterals
  3. iterate on a regularization scheme:
     - swap/insert/collapse so that the *valence* at each vertex approaches 4 while maintaining a valid tessellation
- Driven by the Edge discretizations, which should start out as double the desired size
- Results in an unstructured tessellation unless the underlying triangulation was derived from TFI
- See the function EG_quadTess – page 116.

EGADS Objects – The Model

Models can contain Body, *Effective Topology* and Tessellation Objects, unless they are the output from construction operators. In this case the Model will only contain Body Objects. Models can be created with `EG_makeTopology` (see page 89) and parsed by using `EG_getTopology` (see page 90). These rules apply:

- `nchild` is always the number of Bodies and should be less than or equal to `mtype` (`mtype` can be zero, indicating no ancillary egos).
- You must look at the `oclass` (on the children) of any egos after the Bodies to figure out the kind of object.
- Any Tessellation of EBodies must be listed after the EBody referenced.
- The order of the non-Body children is the same as they were when the Model was created.
- Tessellations and EBodies must be closed when the Model is created.
- Tessellation Objects cannot be reopened once in a Model.
- The Model must contain any Bodies/EBodies referenced by Tessellation Objects and Bodies referenced by EBodies.
- Just like Bodies, Objects in a Model become "owned" by the Model and get deleted when the Model is deleted (and cannot be deleted individually).

EGADS Objects – Others

TRANSFORM

- Used when copying Objects to change the root position and orientation

REFERENCE

- Allows for the management of Objects that refer to other Objects (so that deletion does not invalidate the information)
- An internal Object and is not usually seen by the EGADS programmer

EGADS Objects – Object References

Parent Child References

- Child Objects used with "make" functions are referenced by the resulting Geometric/Topologic parent Object.

Object Deletion

- Objects are deleted individual with EG_deleteObject (all objects are removed with EG_close).
- Referenced child Objects can only be deleted after the parent Object is deleted, i.e. in reverse order of the construction.
- Unconnected Geometric & Topologic Objects (i.e. not in a Body) can be deleted *en masse* by invoking `EG_deleteObject` (see page 52) on the Context.

EGADS Objects – Reference Exceptions

BODY

- When created, all child Objects are copied and stored instead of referenced
- The child Objects can be removed with EG_deleteObject in reverse construction order (or *en masse* with EG_deleteObject on the Context)

MODEL

- A Body, EBody or Tessellation Object can be included in only one MODEL (you will get a "reference error" if violated)
- Because Tessellation and EBody Objects reference Body Objects, the Body may need to be copied before creating Tessellations and EBodies if any are to be included in a Model
- Deleting a Model also deletes all child Objects contained within the Model

EGADS/EGADSlite API

The following pages provide a reference for the EGADS API. Each block describes the function *signature* first using C/C++, then Fortran, then the Python call in violet (when using pyEGADS) and last the Julia call in green (when using jlEGADS). For C/C++/Fortran:

- Function names begin with "EG_" (C/C++)
- Function names begin with "IG_" for the FORTRAN bindings
- Functions almost always return an integer *error code*
- *Object-based* – procedural, usually with the first argument an ego
- Signatures usually have the inputs first, then output argument(s)
- Some outputs may be pointers to lists of *things*
  EG_free (page 63) needs to be used when marked as "freeable"
- El indicates an EGADSlite, *ET* an *Effective Topology* function, dot indicates sensitivity functions exist

See $ESP_ROOT/include/egads.h & egads_dot.h for a complete listing of the functions.
See $ESP_ROOT/include/egadsErrors.h for a list of the return code defines.

EGADS Python API

The Python EGADS API is built on ctypes and mirrors the C/C++ API.
Methods have similar names and arguments, which are ordered consistently when possible (optional arguments are placed last).
C-arrays with strides are lists of tuples.

Import statement: from pyEGADS import egads
Main API classes: egads.Context egads.ego egads.c_ego

- c_ego is a ctypes struct for C function arguments of C ego type
- Python classes Context and ego wrap a c_ego and implement EGADS API
  - The wrapped c_ego is automatically deleted when a Python class is created from an egads method
- Python classes can be created using a c_ego generated outside of egads using the egads.c_to_py(c_obj, deleteObject=False) function
  - deleteObject indicates if the c_ego should be automatically deleted
- The c_ego is retrieved from with object.py_to_c(takeOwnership=False)
  - takeOwnership=True indicates the returned c_ego will no longer be automatically deleted

EGADS Julia API

The Julia EGADS API mirrors the C/C++ API.

Methods have same names and similar arguments (ordered), **except**

- Optional arguments (declared after ";") use keywords
- Arguments indicating array size are excluded

1D Arrays are indicated as [ ] and 2D Arrays as [ ][ ]

- Functions with argument [ ]([ ]) take 1DArray (flattened) or 2DArray
- Functions with argument DataType ([ ]) take single value or 1DArray

Import statement: import egads

Usage: `egads.function_name()`

Main API structures: egads.Ctxt, egads.Ego

- In this document, the prefix `egads.` is omitted

Context and Ego are Julia structures wrapping a C ego type

- They can be created using a C ego generated outside of egads calling
  egads.Context(obj=ego) egads.Ego(ego,ctxt=Context)
- The wrapped ego is automatically deleted using Julia finalizers

Functions modifying input values use signature ! eg., `egads.function!()`

Functions **don't** return icode status. Rather, an internal error is raised

EGADS API – Utility & IO Functions

Get revision

```
      EG_revision(int *imajor, int *iminor, const char **OCCrev);
call IG_revision(I*4  imajor, I*4  iminor, C**          OCCrev)
      imajor, iminor, OCCrev = egads.revision()
      imajor, iminor, OCCrev = revision()
```

imajor	the returned major revision
iminor	the returned minor revision number
OCCrev	the returned revision of OpenCASCADE in use

Returns the version information for both EGADS and OpenCASCADE.

Open EGADS

```
icode = EG_open(ego *context);
icode = IG_open(I*8  context)
        context = egads.Context()
        context = Context()
```

context	the returned Context Object
icode	the integer return code

Opens and returns a Context object. This is required for the use of all EGADS (except for the above).

EGADS API – Utility & IO Functions

Close a Context El

```
icode = EG_close(ego context);
icode = IG_close(I*8 context)
        del context
```

context the Context Object to close

icode the integer return code

Cleans up and closes the Context.

Delete Object El

```
icode = EG_deleteObject(ego object);
icode = IG_deleteObject(I*8 object)
        del object
```

object the Object to delete

icode the integer return code

Deletes an Object (if possible). A positive return indicates that the Object is still referenced by this number of other Objects and has not been removed from the Context. If the Object is the Context then all Geometry/Topology Objects in the Context are deleted except those attached to Body/EBody or Model Objects. You cannot delete lesser *Effective Topology* Objects than an EBody.

El Note: Only Objects created in an EGADSlite session may be deleted.

EGADS API – Utility & IO Functions

Read Geometric data from a File

```
icode = EG_loadModel(ego context, int bitFlag, const char *name,
                     ego *model);
icode = IG_loadModel(I*8 context, I*4 bitFlag, C**          name,
                     I*8  model)
model = context.loadModel(name, bitFlag=0)
model = loadModel(context::Context, bitFlag::Int, name::string)
```

context	the Context Object to receive the geometry
bitFlag	Options (additive):
	1 Don't split closed and periodic entities
	2 Split to maintain at least C^1 in BSPLINEs
	4 Don't maintain Units on STEP/IGES read (always millimeters)
	8 Try to merge Edges and Faces (with same geometry)
	16 Load unattached Edges as WireBodies (stp/step & igs/iges)
name	path of file to load (with extension – case insensitive):
	igs/iges IGES file
	stp/step STEP file
	brep native OpenCASCADE file
	egads native file format with persistent Attributes (splits ignored)
model	the returned Model Object that was read
icode	the integer return code

Loads and returns a Model Object from disk and puts it in the Context.

See page 55 for more information on STEP & IGES import/export

EGADS API – Utility & IO Functions

Writes the Model to a File

```
icode = EG_saveModel(const ego object, const char *name);
icode = IG_saveModel(I*8        object, C**          name)
        object.saveModel(name, overwrite=False)
        saveModel!(object::Ego, name::string; overwrite::Bool)
```

object the Model Object to write

name path of file to write, type based on extension (case insensitive):

igs/iges	IGES file
stp/step	STEP file
brep	a native OpenCASCADE file
egads	a native file format with persistent Attributes and the ability to write EBody and Tessellation data

icode the integer return code

Writes the BReps (with optional Tessellation and EBody Objects) contained in the Model to disk. Only writes BRep data for anything but EGADS output. Will not overwrite an existing file of the same name unless `overwrite=True`.

Notes:

1. object can be a single Body for convenience
2. See page 55 for more information on STEP & IGES import/export

Notes on STEP/IGES Handling

Length Units

EGADS is unitless but the file standards are not. To deal with this the attribute ".lengthUnits" (which is set to a string) is used:

- On import (EG_loadModel):
  - Any Body loaded has ".lengthUnits" set to the import unit designation
- On export (EG_saveModel):
  - If ".lengthUnits" is found on the Model Object this unit string is used
  - Otherwise all Bodies are examined for ".lengthUnits" and if any is found it is used
  - If none are found, then "millimeters" is used
  - If there is any inconsistency when examining multiple Bodies – "millimeters" is used

Attributes

STEP/IGES can only mark Topology with "Name", "Layer" and "Color". In EGADS, the "Name" string attribute is handled on all topological objects, "Color" on Faces and Edges, during import/export.

"Color" may be one of "red", "lred", "green", "lgreen", "blue", "lblue", "yellow", "magenta", "cyan", "white", "black", or three RGB $\in [0, 1]$ reals.

Notes:

- STEP supports Body attributes "ColorFace" and "ColorEdge" for setting Body defaults.
- STEP WireBodies do not support Edge "Color" (use Body "ColorEdge") or Node "Name"
- Edge attributes do not export to IGES when the Edge is associated with two or more Faces.
- IGES does not support "Name" on Nodes

EGADS API – Utility & IO Functions

Update Thread ID in Context

```
icode = EG_updateThread(ego context);
icode = IG_updateThread(I*8 context)
        context.updateThread()
        updateThread!(context::Context)
```

context	the Context Object to update
icode	the integer return code

Resets the Context's owning thread ID to the thread calling this function.

Make a Transform

```
icode = EG_makeTransform(ego context, double *mat, ego *xform);
icode = IG_makeTransform(I*8 context, R*8     mat, I*8  xform)
xform = context.makeTransform(mat)
xform = makeTransform(context::Context, mat::Float[][])
```

context	the Context
mat	the 12 values of the translation/rotation matrix
xform	the returned Transformation Object
icode	the integer return code

Makes a Transformation Object from a translation/rotation matrix. The rotation portion [3][3] must be an orthonormal matrix with a single scale.

EGADS API – Utility & IO Functions

Get matrix from Transform Object

```
icode = EG_getTransform(const ego xform, double *mat);
icode = IG_getTransform(I*8       xform, R*8     mat)
  mat = xform.getTransform()
  mat = getTransform(xform::Ego)
```

xform	the Transformation Object
mat	the filled 12 values of the translation/rotation matrix
icode	the integer return code

Returns the transformation information. This appears like is a column-major matrix that is 4 columns by 3 rows and could be thought of as [3][4] in C/C++ (though is flat) and in Fortran dimensioned as (4, 3).

Copy and flip the orientation of an Object

```
    icode = EG_flipObject(const ego object, ego *newObject);
    icode = IG_flipObject(I*8       object, I*8  newObject)
newObject = object.flipObject()
newObject = flipObject(object::Ego)
```

object	the Object to flip
newObject	The resultant new Object
icode	the integer return code

Creates a new EGADS Object by copying and reversing the input object. Can be Geometry (flip the parameterization) or Topology (reverse the sense). Not for Node, Edge, Body or Model. Surfaces reverse only the *u* parameter.

Copy and optionally Transform an Object

```
 icode = EG_copyObject(const ego object, void *other, ego *newObj);
 icode = IG_copyObject(I*8       object, I*8   other, I*8  newObj)
newObj = object.copy(other, other=None)
newObj = copyObject(object::Ego; other::Ego)
```

object	the Object to copy
other	a Transformation Object, a Body Object, NULL for a strict copy, or a vector of doubles
newObj	The resultant new Object
icode	the integer return code

Creates a new EGADS Object by copying and optionally transforming the input object. A Tessellation or PCurve Object cannot be transformed. For a Tessellation Object, other can be a vector of displacements that is 3 times the number of vertices of doubles in length to *morph* the tessellation. Also, if object is a Tessellation Object or an EBody Object and other is a Body Object, the existing Object is copied but associated with the Body specified (not the original referenced object). Note that other is not checked if it is compatible with the original referenced Body.

If other is a Context, then object is copied to this target Context. This is useful in multithreaded settings.

Use EG_copyGeometry_dot when requiring sensitivities during construction.

EGADS API – Utility & IO Functions

Copy an Object to the specified Context

```
 icode = EG_contextCopy(ego context, const ego object, ego *newObj);
 icode = IG_contextCopy(I*8 context, I*8       object, I*8  newObj)
newObj = context.contextCopy(object)
newObj = contextCopy(context::Context; object::Ego)
```

context	the Context to put the copy (must be a Body for copying a Tessellation Object)
object	the Object to copy – can be either topology or geometry (but not a PCurve) Tessellation Objects may be copied but context must be the corresponding Body in the appropriate Context (usually copied before copying the tessellation) Note: object must not be in the Context
newObj	The resultant new Object
icode	the integer return code

This is useful in multithreaded settings when you wish to copy an object that exists in a different Context/thread. Use EG_copyObject (page 58) when copying from the object's context/thread to the context specified by other.

EGADS API – Utility & IO Functions

Get information about an Object *ET*, EI

```
icode = EG_getInfo(const ego object, int *oclass, int *mtype,
                   ego *topObj, ego *prev, ego *next);
icode = IG_getInfo(I*8       object, I*4  oclass, I*4  mtype,
                   I*8  topObj, I*8  prev, I*8  next);
oclass, mtype, topObj, prev, next = object.getInfo()
oclass, mtype, topObj, prev, next = getInfo(object::{Ego,Context})
```

object	the queried Object
oclass	the returned Object Class
mtype	the returned Member Type
topObj	the returned the top level Body/EBody/Model that *owns* object or Context
prev	the returned previous Object in the threaded list (NULL at Context)
next	the returned next Object in the threaded list (NULL is the end of the list)
icode	the integer return code

Queries Object level information. mtype's meanings depend on the returned oclass value.
The arguments topObj, prev and/or next can be NULL if you do not need these egos.

EGADS API – Utility & IO Functions

Get the Context

```
  icode = EG_getContext(ego object, ego *context);
  icode = IG_getContext(I*8 object, I*8 *context)
context = object.context
context = object.ctxt
```

object	the queried Object
context	the returned owning Context
icode	the integer return code

Returns the Context given an object. The context is a property in Python.

Set the Verbosity Level

El

```
icode = EG_setOutLevel(ego context, int outLevel);
icode = IG_setOutLevel(I*8 context, I*4 outLevel)
        context.setOutLevel(outLevel)
        setOutLevel(context::Context, outLevel::Int)
```

context	the Context
outLevel	the verbosity level: 0-silent to 3-debug
icode	the integer return code

Sets the EGADS verbosity level, the default is 1. Success returns the old outLevel.

EGADS API – Utility & IO Functions

Writes a Model to a stream

```
 icode = EG_exportModel(ego model, size_t *nbyte, char **stream);
 icode = IG_exportModel(I*8 model, I*8     nbyte, CPTR   stream)
stream = model.exportModel()
stream = exportModel(model::Ego)
```

model	the Model Object to export
nbyte	the returned number of bytes in stream
stream	the returned pointer to the byte-stream (freeable)

Create a stream of data serializing the objects in the Model (including EBodies and Tessellations).

Loads a Model from a stream — EL only

```
icode = EG_importModel(ego context, const size_t *nbyte,
                       const char **stream, ego *model);
icode = IG_importModel(I*8 context, I*8          nbyte,
                       CPTR         stream, I*8  model)
model = importModel(stream::UInt[])
```

context	the Context Object to place the import
nbyte	the number of bytes in stream
stream	the pointer to the byte-stream
model	the returned Model Object

Deserialize the stream into the objects (Bodies/EBodies/Tessellations) that make up the returned Model.

EGADS API – Utility & IO Functions

Memory Functions

```
            EG_free(void *ptr);
       call IG_free(CPTR  ptr)

void *ptr = EG_alloc(size_t nbytes);
    icode = IG_alloc(I*4    nbytes, CPTR ptr)

void *ptr = EG_calloc(size_t nele, size_t size);
    icode = IG_calloc(I*4    nele, I*4   size, CPTR ptr)

void *ptr = EG_reall(void *pointer, size_t nbytes);
    icode = IG_reall(CPTR  pointer, I*4    nbytes, CPTR ptr)

char *str = EG_strdup(const char *string);
```

These functions need to be used instead of the C/C++ variants for persistent memory due to the need to allocate/free from the same DLL under Windows.

None of this is necessary within pyEGADS except for one exception – egads.free(ptr) releases memory returned from a ctypes interface

EGADS API – Attribution

Add an Attribute to an Object

```
icode = EG_attributeAdd(ego object, const char *name, int type,
                        int len, const int *ints, const double *reals,
                        const char *string);
icode = IG_attributeAdd(I*8 object, C**          name, I*4 type,
                        I*4 len, I*4         ints, R*8           reals,
                        C**           string)
object.attributeAdd(name, attrVal)
attributeAdd!(object::Ego, name::String, attrVal::{Number[],String})
```

object	the Object to attribute
name	the name of the attribute
type	the attribute type: ATTRINT, ATTRREAL, ATTRSTRING, ATTRCSYS† or ATTRPTR
len	the number of integers or reals (ignored for strings and pointers)
ints	the integers for ATTRINT
reals	the floating-point data for ATTRREAL or ATTRCSYS
string	the character string pointer for ATTRSTRING or ATTRPTR types
icode	the integer return code

Notes: Only the one appropriate attribute value (of ints, reals or string) is required.

† Use – `attrVal = egads.csystem(reals)` to make a CSYS value.

Delete an Attribute from an Object

```
icode = EG_attributeDel(ego object, const char *name);
icode = IG_attributeDel(I*8 object, C**          name)
        object.attributeDel(name)
        attributeDel!(object::Ego; name::String)
```

object the Object
name the name of the attribute to delete
icode the integer return code

Deletes an attribute from the Object. If the name is NULL (or no argument) then all attributes are removed from this Object.

The number of Object Attributes El

```
icode = EG_attributeNum(ego object, int *nAttr);
icode = IG_attributeNum(I*8 object, I*4  nAttr)
nAttr = object.attributeNum()
nAttr = attributeNum(object::Ego)
```

object the Object
nAttr the returned number of attributes attached to the Object
icode the integer return code

Returns the number of attributes found with this object.

Return an Attribute on an Object EI

```
  icode = EG_attributeRet(ego object, const char *name, int *type,
                          int *len, const int **ints,
                          const double **reals, const char **string);
  icode = IG_attributeRet(I*8 object, C**          name, I*4  type,
                          I*4  len, I*4          ints,
                          R*8             reals, C**          string)
attrVal = object.attributeRet(name)
attrVal = attributeRet(object::Ego,name::String)
```

object	the Object to query
name	the name to query
type	the type: ATTRINT, ATTRREAL, ATTRSTRING, ATTRCSYS or ATTRPTR
len	the returned number of integers or reals
ints	the returned pointer to integers for ATTRINT
reals	the returned pointer to floating-point data for ATTRREAL or ATTRCSYS
string	the returned pointer to a character string for ATTRSTRING or ATTRPTR types
icode	the integer return code

Notes: Only the appropriate attribute value (of ints, reals or string) is returned.
Care must be taken with the string variable in Fortran not to overstep the declared length.
The CSys (12 reals) is returned in reals after the len values.

EGADS API – Attribution

Get an Attribute on an Object

```
icode = EG_attributeGet(ego object, int index, const char **name,
                        int *type, int *len,   const int  **ints,
                        const double **reals,  const char **string);
icode = IG_attributeGet(I*8 object, I*4 index, C**          name,
                        I*4  type, I*4  len,   I*4          ints,
                        R*8            reals,  C**          string)
name, attrVal = object.attributeGet(index)
name, attrVal = attributeGet(index::Int)
```

object	the Object to query
index	the index (1 to nAttr from EG_attributeNum)
name	the returned name
type	the type: ATTRINT, ATTRREAL, ATTRSTRING, ATTRCSYS or ATTRPTR
len	the returned number of integers or reals
ints	the returned pointer to integers for ATTRINT
reals	the returned pointer to floating-point data for ATTRREAL or ATTRCSYS
string	the returned pointer to a character string for ATTRSTRING or ATTRPTR types
icode	the integer return code

Notes: Only the appropriate attribute value (of ints, reals or string) is returned.
Care must be taken with the string variable in Fortran not to overstep the declared length.
The CSys (12 reals) is returned in reals after the len values.

EGADS API – Attribution

Copy the Attributes from an Object to another

```
icode = EG_attributeDup(ego src, ego dst);
icode = IG_attributeDup(I*8 src, I*8 dst)
        dst.attributeDup(src)
        attributeDup!(src::Ego,dst::Ego)
```

src	the source Object
dst	the Object to receive src's attributes
icode	the integer return code

Deletes an attribute from the destination Object and then copies the source's attributes to the destination. ATTRPTR attributes copy the pointer, other types allocate new data and copy the contents of the source.

Change Attribute Mode

```
icode = EG_setFullAttrs(ego context, int attrFlag);
icode = IG_setFullAttrs(I*8 context, I*4 attrFlag)
        context.setFullAttrs(attrFlag)
        setFullAttrs!(context::Context, attrFlag::Int)
```

context	the Context Object
attrFlag	the mode flag: 0 – the default scheme, 1 – full attribution mode
icode	the integer return code

Sets the attribution mode for the Context.

EGADS API – Full Attribution

- `EG_attributeAdd`'s functionality is the same in both modes. It overwrites an existing attribute with the same name. The name can have the sequence number (when overwriting, not adding). It is an error if the name with sequence does not exist. If the name of the attribute is the "root" name of an existing sequence, this raises an error. Use `EG_attributeAddSeq` to add additional attributes with the same root name to a sequence.
- `EG_attributeDel`, given a name with a sequence number, only deletes that attribute. Note: this will cause resequencing of the attributes such that there is no gap in the attribute sequence numbering. If only one attribute remains in the sequence, the sequence number is removed. Given a name without a sequence number, it will delete all attributes with that root name.
- `EG_attributeNum` returns the number of all attributes including those with sequence numbers.
- `EG_attributeGet` functionality is equivalent in either mode.
- `EG_attributeRet` accepts names with sequence numbers. An error is raised if the input name does not have a sequence number and there are multiple attributes in the sequence. See `EG_attributeRetSeq` on page 72.
- `EG_attributeDup`'s functionality changes depending on the mode. With full attribution it follows the merge rules seen on page 15. That is, if the destination object already has the attributes they will not be overwritten. If you want to overwrite the existing attributes in full mode, invoke `EG_attributeDel` with NULL and then call `EG_attributeDup`.

EGADS API – Full Attribution

Add an Attribute to an Object

```
icode = EG_attributeAddSeq(ego object, const char *name, int type,
                           int len, const int *ints,
                           const double *reals, const char *string);
icode = IG_attributeAddSeq(I*8 object, C**          name, I*4 type,
                           I*4 len, I*4         ints,
                           R*8             reals, C**          string)
object.attributeAddSeq(name, attrVal)
attributeAddSeq!(obj::Ego, name::String, attrVal::{Number[],String})
```

object	the Object to attribute
name	the name of the attribute
type	the attribute type: ATTRINT, ATTRREAL, ATTRSTRING, ATTRCSYS† or ATTRPTR
len	the number of integers or reals (ignored for strings and pointers)
ints	the integers for ATTRINT
reals	the floating-point data for ATTRREAL or ATTRCSYS
string	the character string pointer for ATTRSTRING or ATTRPTR types
icode	the integer return code or sequence number (0, 2 and on)

Notes: Only the appropriate attribute value (of ints, reals or string) is required.

† Use – `attrVal = egads.csystem(reals)` to make a CSYS value.

If there are no attributes with this name on the object this acts just like `EG_attributeAdd`.

The number of Sequenced Attributes El

```
icode = EG_attributeNumSeq(ego object, const char *name, int *nSeq);
icode = IG_attributeNumSeq(I*8 object, C**          name, I*4  nSeq)
 nSeq = object.attributeNumSeq(name)
 nSeq = attributeNumSeq(object::Ego, name::String)
```

object	the Object
name	the name of the attribute
nSeq	the returned number of sequence attributes with the `name` 0 for no sequencing, 2 or more for the number of attributes in the root name sequence
icode	the integer return code

Returns the number of named sequenced attributes found on this object.

EGADS API – Full Attribution

Return a Sequenced Attribute on an Object EI

```
icode = EG_attributeRetSeq(ego object, const char *name, int index,
                           int *type, int *len, const int **ints,
                           const double **reals, const char **string);
icode = IG_attributeRetSeq(I*8 object, C**          name, I*4 index,
                           I*4  type, I*4  len, I*4          ints,
                           R*8             reals, C**          string)
attrVal = object.attributeRetSeq(name, index)
attrVal = attributeRetSeq(object::Ego, name::String, index::Int)
```

object	the Object to query
name	the "root" name to query
index	the sequence number (1 to nSeq)
type	the type: ATTRINT, ATTRREAL, ATTRSTRING, ATTRCSYS or ATTRPTR
len	the returned number of integers or reals
ints	the returned pointer to integers for ATTRINT
reals	the returned pointer to floating-point data for ATTRREAL or ATTRCSYS
string	the returned pointer to a character string for ATTRSTRING or ATTRPTR types
icode	the integer return code

Notes: Only the appropriate attribute value (of ints, reals or string) is returned.
Care must be taken with the string variable in Fortran not to overstep the declared length.
The CSys (12 reals) is returned in reals after the len values.

EGADS API – Geometry

Create a Geometry Object dot

```
icode = EG_makeGeometry(ego context, int oclass, int mtype, ego rGeom,
                        const int *ints, const double *reals,
                        ego *nGeom);
icode = IG_makeGeometry(I*8 context, I*4 oclass, I*4 mtype, I*8 rGeom,
                        I*4         ints, R*8           reals,
                        I*8  nGeom)
nGeom = context.makeGeometry(oclass, mtype, reals, ints=None,
                             geom=None)
nGeom = makeGeometry(ctxt::Ctxt, oclass::Int, mtype::Int; rGeom::Ego,
                     reals::Float[]([]), ints::Int[])
```

context	the Context Object
oclass	the Object Class: PCURVE, CURVE or SURFACE
mtype	the Member Type (depends on oclass)
rGeom	the reference Geometry Object (if none use NULL)
ints	the integer information (if none use NULL)
reals	the real data used to construct the geometry
nGeom	the returned pointer to the new Geometry Object
icode	the integer return code

Notes: ints is required for either mtype = BEZIER or BSPLINE.
See pages 16-29 for a complete listing of oclass/mtype data requirements.

EGADS API – Geometry

Query a Geometry Object dot, El

```
icode = EG_getGeometry(ego object, int *oclass, int *mtype,
                       ego *rGeom, int **ints, double **reals);
icode = IG_getGeometry(I*8 object, I*4  oclass, I*4  mtype,
                       I*8  rGeom, I*4   ints, R*8       reals)
oclass, mtype, reals, ints, rGeom = object.getGeometry()
oclass, mtype, reals, ints, rGeom = getGeometry(object::Ego)
```

object	the Geometry Object
oclass	the returned Object Class: PCURVE, CURVE or SURFACE
mtype	the returned Member Type (depends on oclass)
rGeom	the returned reference Geometry Object (NULL if none)
ints	the returned pointer to integer information (NULL if none) (*freeable*)
reals	the returned pointer to real data used to describe the geometry (*freeable*)
icode	the integer return code

Notes: ints is returned for either mtype = BEZIER or BSPLINE.
See pages 16-29 for a complete listing of oclass/mtype data information.

EGADS API – Geometry

Create a Surface by *skinning* Curves

```
  icode = EG_skinning(int nCurve, ego *curves, int degree,
                      ego *bspline);
  icode = IG_skinning(I*4 nCurve, I*8  curves, I*4 degree,
                      I*8  bspline)
bspline = egads.skinning(curves, degree=3)
bspline = skinning(curves::Ego[], degree::Int)
```

nCurve	the number of BSpline curves to *skin*
curves	a pointer to a vector of egos containing non-periodic, non-rational BSPLINE curves properly positioned and ordered
degree	degree of the BSpline used in the *skinning* direction
bspline	the returned pointer to the new BSpline Surface Object
icode	the integer return code

This function produces a BSpline Surface that is not fit or approximated in any way, and is true to the input curves.

EGADS API – Geometry

Create an Object by Fitting data to a BSpline dot

```
icode = EG_approximate(ego context, int mDeg, double tol,
                       const int *sizs, const double *xyz, ego *bspl);
icode = IG_approximate(I*8 context, I*4 mDeg, R*8    tol,
                       I*4         sizs, R*8          xyz, I*8  bspl)
 bspl = context.approximate(sizs, xyz, mDeg=0, tol=1.e-8)
 bspl = approximate(context::Ctxt, sizes::Int[], xyz::Float[][];
                    mDeg::Int, tol::Float)
```

context	the Context Object
mDeg†	the maximum degree used by OpenCASCADE [3-8], or cubic by EGADS [-3–2]: -1/0 – fixes the bounds and uses natural end conditions -2/1 – fixes the bounds and maintains the slope input at the bounds -3/2 – fixes the bounds & quadratically maintains the slope at 2^{nd} order
tol	is the tolerance to use for the BSpline approximation procedure, zero for a SURFACE fit (OpenCASCADE)
sizs	a vector of 2 integers that specifies the size and dimensionality of the data. If the second is zero, then a CURVE is fit and the first integer is the length of the number of $[x, y, z]$ triads. If the second integer is nonzero, then the input data reflects a 2D map.
xyz	the data to fit (3 times the number of points in length)
bspl	the returned pointer to the new BSPLINE Geometry Object
icode	the integer return code

† Notes: negative indicates periodic where the first point must be identical to the last; for SURFACEs the periodicity may only be in U; periodic CURVEs must be -1 only; this forces equally spaced knots; the result is C2 but not a *periodic* BSPLINE.

Create an Object by Fitting a BSpline to triangles

```
icode = EG_fitTriangles(ego context, int len, double *xyzs, int ntris,
                        const int *tris, const int *tric, double tol,
                        ego *bspline);
icode = IG_fitTriangles(I*8 context, I*4 len, R*8     xyzs, I*4 ntris,
                        I*4         tris, I*4         tric, R*8    tol,
                        I*8  bspline)
bspline = context.fitTrianges(xyzs, tris, tric=None, tol=1e-7)
bspline = fitTriangles(ctxt::Ctxt, xyzs::Float[]([]), tris::Int[]([]);
                       tric::Int[], tol::Float)
```

context	the Context Object
len	the number of vertices in the triangulation
xyzs	the data to fit (3 times len in length)
ntris	the number of triangles
tris	the pointer to triangle indices (1 bias) (3 times ntris in length)
tric	the pointer to neighbor triangle indices (1 bias) – 0 or (-) at bounds NULL – will compute (3 times ntris in length, if not NULL)
tol	the is the tolerance to use for the BSpline approximation procedure
bspline	the returned pointer to the new Geometry Object
icode	the integer return code

Computes and returns the resultant object created by approximating the triangulation by a BSpline surface.

Insert additional Knots into a BSpline

```
icode = EG_addKnots(ego bspline,
                    int minDegU, int nU, const double *Us,
                    int minDegV, int nV, const double *Vs, ego *nbsp);
icode = IG_addKnots(I*8 bspline,
                    I*4 minDegU, I*4 nU, R*8           Us,
                    I*4 minDegV, I*4 nV, R*8           Vs, I*8  nbsp)
nbsp  = bspline.addKnots(minDegU, Us, minDegV, Vs)
nbsp  = addKnots(bspline::Ego, minDegU::Int, Us::Float[],
                               minDegV::Int, Vs::Float[])
```

bspline	the BSpline PCurve, Curve or Surface Object
minDegU	the minimum Udegree in the resulting BSpline (Degree for PCurve/Curve)
nU	the number of U Knots to insert (Knots for PCurve/Curve)
Us	the UKnot values to insert (may be repeated) (nU in length) (Knots for PCurve/Curve)
minDegV	the minimum Vdegree in the resulting BSpline (Ignored for PCurve/Curve)
nV	the number of V Knots to insert (Ignored for PCurve/Curve)
Vs	the VKnot values to insert (may be repeated) (nV in length) (Ignored for PCurve/Curve)
nbsp	the returned pointer to the new BSpline Geometry Object
icode	the integer return code

The shape of resulting BSpline geometry is unchanged.

Create a CURVE by taking an isocline of a SURFACE

```
icode = EG_isoCline(ego surface, int iUV, double value, ego *curve)
icode = IG_isoCline(I*8 surface, I*4 iUV, R*8    value, I*8  curve)
curve = surface.isoCline(iUV, value)
curve = isoCline(surface::Ego, iUV::Int, value::Float)
```

surface	the Surface Object
iUV	the type of isocline: UISO (0) constant U – or – VISO (1) constant V
value	the value used for the isocline
curve	pointer to the returned isocline curve
icode	the integer return code

Computes from the input surface and returns the isocline curve.

Check if PCURVE is an isocline

```
icode = EG_isIsoPCure(ego pcurve, int *iUV, double *value, int *fwd)
icode = IG_isIsoPCure(I*8 pcurve, I*4  iUV, R*8     value, I*4  fwd)
isiso, iso, value, fwd = pcurve.isIsoPCure()
isiso, iso, value, fwd = isIsoPCure(pcurve::Ego)
```

pcurve	the PCurve Object
iUV	type of isocline (may be NULL): UISO (0) constant U – or – VISO (1) constant V
value	the value of the isocline (may be NULL)
fwd	direction of the PCurve (SFORWARD (1) - Forward, SREVERSE (-1) - Reversed)
icode	the integer return code (EGADS_SUCCES if pcurve is an iso, EGADS_NOTFOUND otherwise)

EGADS API – Geometry/Topology

Returns the range and periodicity — dot, *ET*, El

```
icode = EG_getRange(ego object, double *range, int *periodic);
icode = IG_getRange(I*8 object, R*8     range, I*4  periodic)
range, periodic = object.getRange()
range, periodic = getRange(object::Ego)
```

object	the input Object (PCURVE, CURVE, EDGE, EEDGE, SURFACE, FACE or EFACE)
range	PCURVE, CURVE, EDGE, EEDGE – 2 vales are filled: t_{start} and t_{end} SURFACE, FACE, EFACE – 4 values are filled: u_{min}, u_{max}, v_{min} and v_{max}
periodic	0 for non-periodic, 1 for periodic in t or u, 2 for periodic in v (or-able)
icode	the integer return code

Compute the arc-length of an Object — *ET*, El

```
icode = EG_arcLength(ego object, double t1, double t2, double *alen);
icode = IG_arcLength(I*8 object, R*8    t1, R*8    t2, R*8     alen)
 alen = object.arcLength(t1, t2)
 alen = arcLength(object::Ego, t1::Float, t2::Float)
```

object	the input Object (PCURVE, CURVE or EDGE)
t1	The starting t value
t2	The end t value
alen	the returned resultant arc-length
icode	the integer return code

EGADS API – Geometry/Topology

Evaluate on the Object

dot, *ET*, El

```
 icode = EG_evaluate(ego object, double *params, double *result);
 icode = IG_evaluate(I*8 object, R*8     params, R*8     result)
result = object.evaluate(params)
result = evaluate(object::Ego, params::Float[])
```

object the input Object

params NODE – ignored (can be NULL); PCURVE, CURVE, EDGE, EEDGE – the t value
SURFACE, FACE, EFACE – u then v

result the filled returned position, 1^{st} and 2^{nd} derivatives:

length ⇒	Node – 3	PCurve – 6	Edge / EEdge Curve – 9	Face / EFace Surface – 18
Position	$[x, y, z]$	$[u, v]$	$[x, y, z]$	$[x, y, z]$
1^{st}	–	$[du, dv]$	$[dx, dy, dz]$	$[dx_u, dy_u, dz_u]$
				$[dx_v, dy_v, dz_v]$
2^{nd}	–	$[du^2, dv^2]$	$[dx^2, dy^2, dz^2]$	$[dx_u^2, dy_u^2, dz_u^2]$
				$[dx_{uv}, dy_{uv}, dz_{uv}]$
				$[dx_v^2, dy_v^2, dz_v^2]$

icode the integer return code – evaluation on EFace may return EGADS_EXTRAPOL

Note: You cannot evaluate a DEGENERATE Edge/EEdge.

Inverse evaluation on the Object *ET*, EI

```
icode = EG_invEvaluate(ego object, double *pos, double *params,
                       double *result);
icode = IG_invEvaluate(I*8 object, R*8     pos, R*8     params,
                       R*8     result)
params, result = object.invEvaluate(pos)
params, result = invEvaluate(object::Ego, pos::Float[])
```

object	the input Object
pos	is $[u, v]$ for a PCURVE and $[x, y, z]$ for all others
params	the returned parameter(s) found for the nearest position on the Object: for PCURVE, CURVE, EDGE or EEDGE the one value is t for SURFACE, FACE or EFACE the 2 values are u then v
result	the closest position found is returned: $[u, v]$ for a PCURVE (len = 2) $[x, y, z]$ for all others (len = 3)
icode	the integer return code

Note: When using this with a Face the timing is significantly slower than making the call with the Face's reference surface (due to the clipping). If you don't need this limiting call EG_invEvaluate with the underlying Surface Object.

Returns the curvature information on the Object *ET*, EI

```
 icode = EG_curvature(ego object, double *params, double *result);
 icode = IG_curvature(I*8 object, R*8     params, R*8     result)
result = object.curvature(params)
curvature, direction = curvature(object::Ego, params::Float([]))
```

object — the input Object

params — parameter(s) used to compute on the Object:
PCURVE, CURVE, EDGE, EEDGE – the t value
SURFACE, FACE, EFACE – u then v

result — the filled returned curvature information:

length ⇒	PCurve – 3	Edge / EEdge Curve – 4	Face / EFace Surface – 8
Direction	Curvature $[dir_u, dir_v]$	Curvature $[dir_x, dir_y, dir_z]$	Curvature1 $[dir1_x, dir1_y, dir1_z]$
Direction			Curvature2 $[dir2_x, dir2_y, dir2_z]$

icode — the integer return code

Note: You cannot get curvature on a DEGENERATE Edge.

EGADS API – Geometry/Topology

Returns other Curve that matches the input Curve

```
icode = EG_otherCurve(ego object, ego curve, double tol, ego *ocurve);
icode = IG_otherCurve(I*8 object, I*8 curve, R*8    tol, I*8  ocurve)
ocurve = object.otherCurve(curve)
ocurve = otherCurve(object::Ego, curve::Ego; tol::Float)
```

object	the input Object (SURFACE or FACE)
curve	the input PCurve or Curve/Edge Object
tol	is the tolerance to use when fitting the output curve
ocurve	the returned approximated resultant Curve or PCurve Object
icode	the integer return code

Produces the PCurve from the Curve/Edge or *vice versa*.

Do the Objects represent the same Geometry?

```
icode = EG_isSame(const ego object1, const ego object2);
icode = IG_isSame(I*8       object1, I*8       object2)
 bool = object1.isSame(object2)
 bool = isSame(object1::Ego, object2::Ego)
```

object1	the first input Object (NODE, CURVE, EDGE, SURFACE or FACE)
object2	the second input Object (to make the comparison)
icode	the integer return code (same is EGADS_SUCCESS, not same is EGADS_OUTSIDE)

EGADS API – Geometry/Topology

Concatenates 2 BSpline curves to make another

```
  icode = EG_mergeBSplineCurves(ego curve1, ego curve2, ego *bspline);
  icode = IG_mergeBSplineCurves(I*8 curve1, I*8 curve2, I*8  bspline)
bspline = curve1.mergeBSplineCurves(curve2)
bspline = mergeBSplineCurves(curve1::Ego, curve2::Ego)
```

curve1	the first input BSpline CURVE Object
curve2	the second input BSpline CURVE Object
bspline	pointer to the returned BSpline CURVE Object
icode	the integer return code

The starting and ending control points are matched and used to mate the curves. The direction of the result is fixed by curve1. The t range is the sum of the 2 input CURVE ranges scaled by arcLength.

Converts geometry to BSPLINE `mtype`

```
  icode = EG_convertToBSpline(ego object, ego *bspline);
  icode = IG_convertToBSpline(I*8 object, I*8  bspline)
bspline = object.convertToBSpline()
bspline = convertToBSpline(object::Ego)
```

object	the input Object (PCURVE, CURVE, EDGE, SURFACE or FACE)
bspline	pointer to the returned BSpline Geometry Object
icode	the integer return code

Computes and returns the BSpline representation of the input Geometry Object.

EGADS API – Geometry/Topology

Converts geometry (with limits) to BSPLINE mtype

```
  icode = EG_convertToBSplineRange(ego object, const double *range,
                                   ego *bspline);
  icode = IG_convertToBSplineRange(I*8 object, R*8           range,
                                   I*8  bspline)
bspline = object.convertToBSpline(range)
bspline = convertToBSplineRange(object::Ego, range::Float[]([]))
```

object	the input Object (PCURVE, CURVE or SURFACE)
range	t range (2) or $[u, v]$ box (first for u then for v – 4) to limit the conversion
bspline	pointer to the returned BSpline Geometry Object
icode	the integer return code

Required when converting Geometry Objects with infinite range.

EGADS API – Topology

oclass	mtype	Notes
MODEL	→	Number of total egos or zero see page 44
BODY	WIREBODY FACEBODY SHEETBODY SOLIDBODY	A single Loop A single Face A single non-manifold or manifold Shell A *Solid*
SHELL	OPEN or CLOSED	
FACE	SREVERSE or SFORWARD	orientation of surface vs. Face
LOOP	OPEN or CLOSED	
EDGE	DEGENERATE ONENODE TWONODE	a single Node marking the collapse of a surface (`nchild` = 1) a CLOSED curve (`nchild` = 1) a normal Edge (`nchild` = 2)
NODE	–	

Create a Topology Object

dot

```
icode = EG_makeTopology(ego context, ego geom, int oclass, int mtype,
                        double *reals, int nchild, ego *children,
                        int *senses, ego *topo);
icode = IG_makeTopology(I*8 context, I*8 geom, I*4 oclass, I*4 mtype,
                        R*8     reals, I*4 nchild, I*8  children,
                        I*4  senses, I*8  topo)
 topo = context.makeTopology(oclass, mtype=0, geom=None, reals=None,
                             children=None, senses=None)
 topo = makeTopology!(ctxt::Context, oclass::Int; mtype::Int,
           geom::Ego,reals::Float[], senses::Int,children::Float([]))
```

context	the Context Object
geom	the reference Geometry Object (if none use NULL)
oclass	the Object Class: NODE, EDGE, LOOP, FACE, SHELL, BODY or MODEL
mtype	the Member Type (depends on oclass – see page 88)
reals	the real data: may be NULL except for NODE that contains the $[x, y, z]$ location and EDGE where the t_{min} and t_{max} (the parametric bounds) are specified
nchild	number of children (lesser) Topological Objects
children	vector of children objects (nchild in length) if a LOOP with a reference SURFACE, then 2*nchild in length (PCurves follow)
senses	a vector of children integer senses: SFORWARD/SREVERSE for LOOP, and SOUTER/SINNER for FACE nchild > 1 (may be NULL for FACE nchild $= 1$)
topo	the returned pointer to the new Topology Object

Query a Topology Object 1/2 *ET*, EI

```
icode = EG_getTopology(ego topo, ego *geom, int *oclass, int *mtype,
                       double *reals, int *nchild, ego **children,
                       int **senses);
icode = IG_getTopology(I*8 topo, I*8  geom, I*4  oclass, I*4  mtype,
                       R*8     reals, I*4  nchild, I*8   children,
                       I*4   senses)
oclass, mtype, geom, reals, children, senses = topo.getTopology()
oclass, mtype, geom, reals, children, senses = getTopology(topo::Ego)
```

topo	the Topology or *Effective Topology* Object to query
geom	the returned reference Geometry Object (can be NULL)
oclass	the returned Object Class: Topology or *Effective Topology*
mtype	the returned Member Type (depends on oclass – see page 88)
reals	the real data (at most 4 doubles are filled): NODE – contains the $[x, y, z]$ location, EDGE where the t_{min} and t_{max} (the parametric bounds) are returned and FACE where the $[u, v]$ box is filled → the limits first for u then for v (4 in length)
nchild	the returned number of children (lesser) Topological Objects
children	the returned pointer to a vector of children objects (nchild in length) if a LOOP with a reference SURFACE, then 2*nchild in length (PCurves follow) if a MODEL – nchild is the number of Body Objects, mtype the total ego count
senses	a vector of senses for the children (LOOPs) or inner/outer for (FACEs & SHELLs)
icode	the integer return code (EGADS_OUTSIDE for an open EBody)

Query a Topology Object 2/2 *ET*

Returns using *Effective Topology*:

EBODY	geom is the source Body Object children are ESHELLs or EFACE (for mtype is FACEBODY) returns EGADS_OUTSIDE if the EBody is still open
ESHELL	children are EFaces
EFACE	no reference geometry, returns $[u, v]$ box for Face collection children are ELoops
ELOOPX	children are EEdges
EEDGE	no ref geometry, returns t range for the Edge collection children are Nodes

Use `EG_getBodyTopos` (page 96) on the EBody with ref as an EFace and oclass as FACE to find all of the Faces in that EFace. The same can be done with Edges/EEdges or use the function `EG_effectiveEdgeList` (page 156).

Create a Face Object

```
icode = EG_makeFace(ego object, int mtype, const double *rdata,
                    ego *face);
icode = IG_makeFace(I*8 object, I*4 mtype, R*8           rdata,
                    I*8  face)
 face = object.makeFace(mtype, rdata=None)
 face = makeFace(object::Ego, mtype::Int; rdata::Float[]([]))
```

object	either a Loop (for a planar cap), a surface with $[u, v]$ bounds, or a Face to be hollowed out
mtype	is either SFORWARD or SREVERSE. SFORWARD gives a Face normal vector consistent with orientation of the Loop or the normal vector of a surface. Ignored when the input object is a Face
rdata	may be NULL for Loops, but must be the limits for a surface (4 values), the hollow/offset distance and fillet radius (zero is for no fillets) for a Face input object (2 values)
face	the resultant returned topological Face Object (a return of EGADS_OUTSIDE is the indication that offset distance was too large to produce any cutouts, and this result is the input object)
icode	the integer return code

This *helper* function creates a simple Face from a Loop or a surface. Also can be used to hollow out a Face with a single Loop. This function creates any required Nodes, Edges and Loops.

Create a Loop Object

```
icode = EG_makeLoop(int nedge, ego *edges, ego geom, double toler,
                    ego *loop);
icode = IG_makeLoop(I*4 nedge, I*8  edges, I*8 geom, R*8    toler,
                    I*8  loop)
loop, edges = egads.makeLoop(edges, geom=None, toler=0.0)
loop, edges = makeLoop!(edges::Ego([]); geom::Ego, toler::Float)
```

nedge	the number of Edge Objects in the list (>= 1)
edges	list of Edge Objects, of which some may be NULL (nedge in length) Note: list entries are NULLified when included in Loops
geom	the Surface Object for non-planar Loops to be used to bound Faces (can be NULL)
toler	tolerance used for the operation (0.0 – use the Edge tolerances)
loop	the resultant Loop Object
icode	the integer return code or the number of non-NULL entries in edges when returned

This *helper* function creates a Loop Object from a list of Edge Objects, where the Edges (not DEGENERATE) do not have to be topologically connected. The tolerance is used to build the Nodes for the Loop. The orientation is set by the first non-NULL entry in the list, which is taken in the positive sense (if closed – otherwise the orientation is not fixed). This is designed to be executed until all list entries are exhausted.

EGADS API – Topology

Create a simple Solid Body

```
icode = EG_makeSolidBody(ego context, int stype, const double *data,
                         ego *body);
icode = IG_makeSolidBody(I*8 context, I*4 stype, R*8           data,
                         I*8  body)
 body = context.makeSolidBody(stype, data)
 body = makeSolidBody(context::Ctxt, stype::Int, data::Float[])
```

context	the Context Object
stype	one of: BOX, SPHERE, CONE, CYLINDER, TORUS
data	length and fill depends on stype:

BOX	6	$[x, y, z]$ then $[dx, dy, dz]$ for the size of box
SPHERE	4	$[x, y, z]$ of center then the radius
CONE	7	apex $[x, y, z]$, base center $[x, y, z]$, then the radius
CYLINDER	7	2 axis points and the radius
TORUS	8	$[x, y, z]$ of center, direction of rotation, then the major radius and minor radius

body	the resultant Solid Body Object
icode	the integer return code

EGADS API – Topology

Creates a non-manifold Wire Body

```
icode = EG_makeNmWireBody(int nObject, ego *objects, double toler,
                          ego *wbody);
icode = IG_makeNmWireBody(I*4 nObject, I*8  objects, R*8    toler,
                          I*8  wbody)
wbody = egads.makeNmWireBody(objects, toler=0.0)
wbody = makeNmWireBody(objects::Ego[]; toler::Float)
```

nObject	the number of Edge Objects in the list objects
objects	a pointer to a vector of Edge Objects to make the Wire Body (nObject in length)
toler	Node tolerance to connect Edges (0.0 indicates the use of the Nodes directly)
wbody	the returned pointer to a Wire Body Object
icode	the integer return code

Notes:
1. The collection of Edges in objects must be connected in a non-manifold manner.
2. If the Edges reflect a simple (manifold) Loop, use `EG_makeTopology` to make the Loop (so that the senses can be set) and then also construct the Wire Body from the Loop.
3. Edges must be given in an order such that every Edge (after the first) creates no more than one new Node.

Queries the Objects in a Body *ET*, El

```
icode = EG_getBodyTopos(const ego body, ego ref, int oclass,
                        int *ntopo, ego **topos);
icode = IG_getBodyTopos(I*8       body, I*8 ref, I*4 oclass,
                        I*4  ntopo, CPTR  topos)
topos = object.getBodyTopos(oclass, ref=None)
topos = getBodyTopos(body::Ego, oclass::Int; ref::Ego)
```

body	the Body/EBody Object
ref	reference Topology Object or NULL. Sets the context for the returned Objects (i.e., all objects of the class oclass in the tree looking towards that class from ref) NULL starts from the body (for example all Nodes in the Body)
oclass	is NODE, EDGE, LOOP, FACE or SHELL – must not be the same class as ref for EBODY can be EEDGE, ELOOPX, EFACE, ESHELL or the above
ntopo	the returned number of Topology Objects
topos	is a returned pointer to the vector of Objects, it is possible that an individual Object may be NULL (*freeable*) Note: the argument can be NULL so the Objects are not filled
icode	the integer return code

This allows for the traversal of the Topology *tree* by jumping levels and/or looking up the hierarchy.

EGADS API – Topology

Get the index of the Object in a Body *ET*, El

```
index = EG_indexBodyTopo(const ego body, const ego obj);
index = IG_indexBodyTopo(I*8       body, I*8       obj)
index = body.indexBodyTopo(obj)
index = indexBodyTopo(body::Ego, obj::Ego)
```

body	the Body/EBody Object
obj	is the Topology Object in the Body/EBody
index	the index (bias 1) or the integer return code (negative)

Get the Object in a Body by index *ET*, El

```
icode = EG_objectBodyTopo(const ego body, int oclass, int index,
                          ego *obj);
icode = IG_objectBodyTopo(I*8       body, I*4 oclass, I*4 index,
                          I*8  obj)
  obj = body.objectBodyTopo(oclass, index)
  obj = objectBodyTopo(body::Ego, oclass::Int, index::Int)
```

body	the Body/EBody Object
oclass	the Topology/*Effective Topology* object class
index	the index (bias 1) of the entity requested
obj	is the returned Topology Object from the Body/EBody
icode	the integer return code

EGADS API – Topology

Compute the Area *ET*

```
icode = EG_getArea(ego object, const double *limits, double *area);
icode = IG_getArea(I*8 object, R*8           limits, R*8      area)
 area = object.getArea(limits=None)
 area = getArea(object::Ego; limits::Float[]([]))
```

object	either a Loop (for a planar cap), a surface with $[u, v]$ bounds or a Face
limits	may be NULL except must contain the limits for a surface (4 words)
area	the resultant surface area returned
icode	the integer return code

Computes the surface area from a Loop, a surface or a Face. The resultant area is negative if a non-planar Loop is left-handed relative to the normal of the associated surface.

Return the Bounding Box info *ET*, El

```
icode = EG_getBoundingBox(const ego object, double *bbox);
icode = IG_getBoundingBox(I*8       object, R*8     bbox)
 bbox = object.getBoundingBox()
 bbox = getBoundingBox(object::Ego)
```

object	any topological object
bbox	6 doubles filled reflecting $[x, y, z]_{min}$ and $[x, y, z]_{max}$
icode	the integer return code

Computes the smallest Cartesian bounding box surrounding the object.

EGADS API – Topology

Returns the Mass Properties *ET*

```
icode = EG_getMassProperties(const ego object, double *props);
icode = IG_getMassProperties(I*8       object, R*8      props)
volume, areaOrLen, CG, I = object.getMassProperties()
volume, areaOrLen, CG, I = getMassProperties(object::Ego)
```

object can be EDGE, LOOP, FACE, SHELL, BODY or *Effective Topology* counterpart

props 14 doubles filled reflecting Volume, Area (or Length), Center of Gravity (3) and the inertia matrix at CG (9)

icode the integer return code

Computes and returns the physical and inertial properties of a Topology Object.
See EG_tessMassProperties (page 136) if you want derivatives.

Do the two Objects represent the same Topology?

```
icode = EG_isEquivalent(const ego topo1, const ego topo2);
icode = IG_isEquivalent(I*8       topo1, I*8       topo2)
 bool = topo1.isEquivalent(topo2)
 bool = isEquivalent(topo1::Ego, topo2::Ego)
```

topo1 the first input Topology Object

topo2 the second input Topology Object (to make the comparison)

icode the integer return code (same is EGADS_SUCCESS, not equal is EGADS_OUTSIDE)

Compares two topological objects for equivalence.

EGADS API – Topology

Inside Predicate — EL

```
icode = EG_inTopology(const ego object, const double *xyz);
icode = IG_inTopology(I*8       object, R*8           xyz)
 bool = object.inTopology(xyz)
 bool = inTopology(object::Ego, xyz::Float[])
```

object	the object, can be EDGE, FACE, SHELL or SOLIDBODY
xyz	the coordinate location to check (3 in length)
icode	the integer return code (in is EGADS_SUCCESS, out is EGADS_OUTSIDE)

Computes whether the point is on or contained within object. Works with Edges and Faces by projection. Shells must be CLOSED.

In Face Predicate — *ET*, EL

```
icode = EG_inFace(const ego face, const double *uv);
icode = IG_inFace(I*8       face, R*8           uv)
 bool = face.inFace(uv)
 bool = inFace(face::Ego, uv::Float[])
```

face	the Face Object
uv	the $[u, v]$ location to check (2 in length)
icode	the integer return code (in is EGADS_SUCCESS, out is EGADS_OUTSIDE)

Queries whether the $[u, v]$ location in the valid part of the Face Object.

Get Edge's UV on Face *ET*, EI

```
icode = EG_getEdgeUV(const ego face, const ego edge, int sense,
                     double t, double *uv);
icode = IG_getEdgeUV(I*8        face, I*8        edge, I*4 sense,
                     I*4     t, R*8      uv)
   uv = face.getEdgeUV(edge, t, sense=0)
   uv = getEdgeUV(face::Ego, edge::Ego, sense::Int, t::Float)
```

face	the Face/EFace Object
edge	the Edge/EEdge Object
sense	can be 0, but must be specified (± 1) if edge is found in face twice, which denotes the position in the Loop to use.
t	the Edge parametric t value
uv	the resultant $[u, v]$ – 2 values filled.
icode	the integer return code – EGADS_TOPOERR when sense is 0 with a double Edge hit.

Notes:
1. Evaluates the Edge/pcurve to get $[u, v]$ on the Face. Use instead of EG_invEvaluate (page 83) at the Face/EFace Object's bounds.

2. Cannot be used on an EFace containing more than one Face and a DEGENERATE EEdge.

EGADS API – Topology

Sews unconnected Faces together

```
icode = EG_sewFaces(int nObject, ego *objects, double toler, int flag,
                    ego *model);
icode = IG_sewFaces(I*4 nObject, I*8  objects, R*8    toler, I*4 flag,
                    I*8  model)
model = egads.sewFaces(objects, toler=0.0, manifold=True)
model = sewFaces(objects::Ego[]; toler::Float, flag::Bool)
```

nObject	the number of Objects in the list objects
objects	a pointer to a vector of egos to sew together (nObject in length) can be Faces, Shells and/or Body Objects (but not WIREBODY)
toler	tolerance used for the operation (0.0 – use Face tolerances)
flag	0 – manifold results 1 – allow for non-manifold results (3 or more Faces connecting to a single Edge)
model	the returned pointer to a Model Object
icode	the integer return code

Creates a Model from a collection of Objects by *sewing* Edges that are closer together than the tolerance. The input list can contain Body (not WIREBODY), Shell and/or Face Objects. After the sewing operation, any loose Faces are made into FaceBody Objects, any open Shells (or non-manifold results) are made into SheetBody Objects, closed manifold Shells become SolidBody Objects and all are returned in the Model.

EGADS API – Topology

Replace Faces in a Body

```
 icode = EG_replaceFaces(const ego body, int nFace, ego *objects,
                         ego *result);
 icode = IG_replaceFaces(I*8       body, I*4 nFace, I*8  objects,
                         I*8  result)
result = body.replaceFaces(objects)
result = replaceFaces(body::Ego, objects::Ego[])
```

body	the Body Object to adjust (either a SHEETBODY or a SOLIDBODY)
nFace	the number of Face pair Objects in the list objects
objects	a pointer to a vector of egos to sew together (2*nFace in length) where the first in the pair must be a Face in body and second is either the Face to use as a replacement or a NULL which indicates that the Face is to be removed
result	the resultant Body Object, either a SHEETBODY or a SOLIDBODY (where the input was a SOLIDBODY and all Faces are replaced in a way that the Loops match up – or – if all inner Shell Faces are removed)
icode	the integer return code

Creates a new SheetBody or SolidBody Object from an input Body and a list of Faces to modify. The Faces are input in pairs where the first must be an Object in the Body and the second either a new Face or NULL. The NULL replacement flags removal of the Face.

Removes Nodes from a Body

```
 icode = EG_removeNodes(const ego body, int nNode, ego *nodes,
                        ego *result);
 icode = IG_removeNodes(I*8       body, I*4 nNode, I*8  nodes,
                        I*8  result)
result = body.removeNodes(nodes)
result = removeNodes(body::Ego, nodes::Ego[])
```

body	the Body Object to adjust (either a FACEBODY, SHEETBODY or a SOLIDBODY)
nNode	the number of Node Objects in the list nodes
nodes	a pointer to a vector of NODE egos (nNode in length)
result	the resultant Body Object, either a FACEBODY, SHEETBODY or a SOLIDBODY depending on the type of body
icode	the integer return code

Creates a new Body (with the same type as input) from a Body Object and a list of Nodes to remove. The Nodes must only touch 2 Edges and these Edges must bound the same 2 Faces (a SHEETBODY or FACEBODY can bound one Face when on Edges without 2 Face neighbors). If the Edge Curves are not BSplines they are converted and concatenated into a single BSpline Curve and the 2 Edges are replaced by one. Note: you cannot remove a Node that will result in a closed Edge.

EGADS API – Topology

Retrieve the Body Object *ET*, EI

```
icode = EG_getBody(const ego object, ego *body);
icode = IG_getBody(I*8       object, I*8  body)
 body = object.getBody()
 body = getBody(body::Ego)
```

object the input topology Object (can be an EBody to retrieve the referenced Body)

body the returned Body/EBody Object (may be NULL if object is not attached to a Body). An Effective object returns an EBody.

icode the integer return code

Return the Tolerance EI

```
icode = EG_getTolerance(const ego topo, double *toler);
icode = IG_getTolerance(I*8       topo, R*8     toler)
toler = topo.getTolerance()
toler = getTolerance(topo::Ego)
```

topo the Topology Object

toler the returned tolerance (Effective Topology inputs will return 0.0)

icode the integer return code

Returns the internal tolerance defined for the Object.

Return the Maximum Tolerance *ET*, EI

```
icode = EG_tolerance(const ego topo, double *toler);
icode = IG_tolerance(I*8       topo, R*8     toler)
toler = topo.tolerance()
toler = tolerance(topo::Ego)
```

topo	the Topology Object
toler	the returned tolerance (Effective Topology returns discrete displacement)
icode	the integer return code

Returns the maximum tolerance defined for the Object's hierarchy.

Sets the Tolerance – Deprecated

```
icode = EG_setTolerance(const ego topo, double toler);
icode = IG_setTolerance(I*8       topo, R*8    toler)
```

topo	the Topology Object
toler	the specified tolerance
icode	the integer return code

Sets the internal tolerance defined for the object. Was useful for SBOs – now use EG_generalBoolean (see page 139).

Find matched Edges between Body Objects

```
icode = EG_matchBodyEdges(const ego body1, const ego body2,
                          double tolScale, int *nMatch, int **matches)
icode = IG_matchBodyEdges(I*8       body1, I*8       body2,
                          R*8    tolScale, I*4  nMatch, CPTR  matches)
matches = body1.matchBodyEdges(body2, tolScale=0.0)
matches = matchBodyEdges(body1::Ego, body2::Ego; tolScale::Float)
```

body1	the first input Body Object
body2	the second Body Object
tolScale	tolerance scale factor, tolScale > 1 relaxes and 1 > tolScale > 0 tightens tolerance (may be 0.0 for default tolerances)
nMatch	the number of matched Edge pairs in the list
matches	pointer to a list of Edge pairs, returned as NULL if nMatch is zero, otherwise it is a pointer to 2*nMatch integers, where each pair are the matching 1-bias indices in the respective bodies (freeable)
icode	the integer return code

Examines the Edges in one Body against all of the Edges in another. If the number of Nodes, the Node locations, the Edge bounding boxes and the Edge arc-lengths match it is assumed that the Edges match. A list of pairs of 1-bias indices is returned.

Find matched Faces between Body Objects

```
icode = EG_matchBodyFaces(const ego body1, const ego body2,
                          double tolScale, int *nMatch, int **matches)
icode = IG_matchBodyFaces(I*8       body1, I*8       body2,
                          R*8    tolScale, I*4  nMatch, CPTR  matches)
matches = body1.matchBodyFaces(body2, tolScale=0.0)
matches = matchBodyFaces(body1::Ego, body2::Ego; tolScale::Float)
```

body1	the first input Body Object
body2	the second Body Object
tolScale	tolerance scale factor, tolScale > 1 relaxes and 1 > tolScale > 0 tightens tolerance (may be 0.0 for default tolerances)
nMatch	the number of matched Face pairs in the list
matches	pointer to a list of Face pairs, returned as NULL if nMatch is zero, otherwise it is a pointer to 2*nMatch integers, where each pair are the matching 1-bias indices in the respective bodies (freeable)
icode	the integer return code

Examines the Faces in one Body against all of the Faces in another. If the number of Loops, number of Nodes, the Node locations, number of Edges, the Face and Edge bounding boxes and the Edge arc-lengths match it is assumed that the Faces match. A list of pairs of 1-bias indices is returned.

Note: This is useful for the situation where there are glancing Faces and a UNION operation fails (or would fail). Simply find the matching Faces and do not include them in a call to EG_sewFaces, see page 102.

Maps the Objects of the Source to the Destination

```
 icode = EG_mapBody(const ego src, const ego dst,
                    const char *fAttr, ego *mapped);
 icode = IG_mapBody(I*8       src, I*8       dst,
                    C**         fAttr, I*8  mapped)
mapped = src.mapBody(dst, fAttr)
mapped = mapBody(src::Ego, dst::Ego, fAttr::String)
```

src	the source Body Object (not a WIREBODY)
dst	the destination Body Object
fAttr	the Face attribute used to map the Faces
mapped	the mapped resultant Body Object copied from dst If NULL and icode is EGADS_SUCCESS, dst is equivalent and can be used directly in EG_mapTessBody – see page 118.
icode	the integer return code

Checks for topological equivalence between src and dst. If necessary, produces a mapping (indices in src which map to dst) and places these as body attributes on mapped (named ".nMap", ".eMap" and ".fMap"). Also may modify BSplines associated with Faces.

Note: It is the responsibility of the caller to have uniquely attributed all Face Objects in both src and dst to aid in the mapping for all but FACEBODYs.

Maps the Objects of the Source to the Destination

```
 icode = EG_mapBody2(const ego src, const char *fAttr,
                     const char *eAttr, ego dst);
 icode = IG_mapBody2(I*8       src, C**          fAttr,
                     C**         eAttr, I*8 dst)
src.mapBody2(fAttr, eAttr, dst)
mapBody2(src::Ego, fAttr::String, eAttr::String, dst::Ego)
```

src	the source Body Object
dst	the destination Body Object
fAttr	the Face attribute used to map the Faces
eAttr	the Edge attribute used to map the Edges
icode	the integer return code

Checks for topological equivalence between src and dst. If necessary, produces a mapping (indices in src which map to dst) and places these as body attributes on dst (named ".nMap", ".eMap" and ".fMap"). Unlike EG_mapBody, EG_mapBody2 also works on FACEBODYs and WIREBODYs.

Note: It is the responsibility of the caller to have uniquely attributed all Face and non degenerate Edge Objects in both src and dst to aid in the mapping.

Computes the Winding Angle along an Edge EI

```
icode = EG_getWindingAngle(ego edge, double t, double *angle);
icode = IG_getWindingAngle(I*8 edge, R*8    t, R*8      angle)
angle = edge.getWindingAngle(t)
angle = getWindingAngle(edge::Ego, t::Float)
```

edge — the input Edge (not DEGENERATE)
returns an error if there are 3 or more Faces attached to the Edge

t — the *t* value along the Edge used to compute the Winding Angle

angle — the returned Winding Angle in degrees (0.0 – 360.0)
This is measured from one Face "winding" around to the other based on the normals
An Edge with a single Face always returns 180.0

icode — the integer return code

EGADS API – Tessellation

Creates a Discrete Object from Geometry

```
icode = EG_makeTessGeom(ego geom, double *limits, int *sizes,
                        ego *tess);
icode = IG_makeTessGeom(I*8 geom, R*8     limits, I*4  sizes,
                        I*8  tess)
 tess = geom.makeTessGeom(limits, sizes)
 tess = makeTessGeom(geom::Ego, limits::Float[], sizes::Int[])
```

geom	the input Object, may be a CURVE or SURFACE
limits	the bounds of the tessellation (like input like the *range* – see EG_getRange, page 81)
sizes	a set of 2 integers that specifies the size and dimensionality of the data. The second is assumed zero for a CURVE and in this case the first integer is the length of the number of evenly spaced (in t) points created. The second integer must be nonzero for SURFACEs and this then specifies the density of the $[u, v]$ map of coordinates produced (again evenly spaced in the parametric sense). If a value of sizes is negative, then the fill is reversed for that coordinate.
tess	the returned resultant Tessellation of the geometric entity
icode	the integer return code

Creates a discretization object from a geometry-based Object.

Returns the Discrete Object data

```
icode = EG_getTessGeom(ego tess, int *sizes, double **xyzs);
icode = IG_getTessGeom(I*8 tess, I*4  sizes, CPTR     xyzs)
sizes, xyzs = tess.getTessGeom()
sizes, xyzs = getTessGeom(tess::Ego)
```

tess	the input geometric Tessellation Object
sizes	a returned (filled) set of 2 integers that specifies the size and dimensionality of the data. If the second is zero, then it is from a CURVE and the first integer is the length of the number of $[x, y, z]$ triads. If the second integer is nonzero then the input data reflects a 2D map of coordinates.
xyzs	the returned pointer to the suite of coordinate data
icode	the integer return code

Retrieves the data associated with the discretization of a geometry-based Object.

Creates a Discrete Object from a Body *ET*, EI

```
icode = EG_makeTessBody(ego body, double *parms, ego *tess);
icode = IG_makeTessBody(I*8 body, R*8     parms, I*8  tess)
 tess = body.makeTessBody(parms)
 tess = makeTessBody(body::Ego, parms::Float[])
```

body — the input Body or closed EBody Object, may be any Body type

parms — a set of 3 parameters that drive the Edge discretization and the Face triangulation. The first is the maximum length of an Edge segment or triangle side (in physical space); a zero is no limit, and a negative value only tessellates Edges. The second is a curvature-based value that looks locally at the deviation between the centroid of the discrete object and the underlying geometry. Any deviation larger than the input value will cause the tessellation to be enhanced in those regions. The third is the maximum interior dihedral angle (in degrees) between triangle facets (or Edge segment tangents for a WIREBODY tessellation), note that a zero ignores this phase.

tess — the returned resultant Tessellation of body

icode — the integer return code

See the next page for attribute-based tessellation control.

Tessellation control at the Topological level

.tParams this attribute can be placed on the Body, individual Faces or Edges which overrides parms locally (the minimums are used). This attribute must be ATTRREAL and have 3 values (as described in EG_makeTessBody).

.tParam like the attribute .tParams, this attribute completely overrides parms locally (without using the minimum).

.tPos this ATTRREAL attribute on an Edge directly sets the ts for interior Edge positions.

.rPos this ATTRREAL attribute sets the relative spacing (in arc-length) for interior Edge positions.

.nPos this ATTRINT attribute sets the number of interior vertices (length is 1). The spacing is set equal in arc-length.

.inserts this ATTRREAL attribute (on a Face) specifies that these vertex $[u, v]$ positions will be inserted into the tessellation. The length must be 2 times the number of inserts.

.insert! like the attribute .inserts, this specifies the $[u, v]$ positions to be inserted, but after these inserts the Face tessellation terminates (i.e., no additional insertions are performed by the normal algorithm).

note:

An ATTRINT attribute .tPos or .rPos of length 1 and containing a zero indicates no interior points.

Convert a Triangulation to Quads *ET*, EI

```
icode = EG_quadTess(ego tess, ego *qtess);
icode = IG_quadTess(I*8 tess, I*8  qtess)
qtess = tess.quadTess()
qtess = quadTess(tess::Ego)
```

tess	the input Tessellation Object (not for WIREBODY)
qtess	the returned fully quadrilateral Tessellation Object
icode	the integer return code

Takes a triangulation as input and outputs a full quadrilateralization of the Body. The algorithm uses the bounds of each Face (the discretization of the Loops) and drives the interior towards regularization (4 quad sides attached to a vertex) without regard to spacing but maintaining a valid mesh. This is the recommended quad approach in that it is robust and does not require manual intervention like EG_makeQuads – page 123 (plus retrieving the quads is much simpler and does nor require invoking EG_getQuads – page 125 and EG_getPatch – page 126).

qtess is a triangle-based Tessellation Object, but with pairs of triangles (as retrieved by calls to EG_getTessFace – page 121) representing each quadrilateral. This is marked by the following attributes on qtess:

- ".tessType" (ATTRSTRING) is set to "Quad"
- ".mixed" with type ATTRINT and the length is the number of Faces in the Body, where the values are the number of quads (triangle pairs) per Face. Single triangles are followed by triangle pairs for a Face with both triangle and quads.

EGADS API – Tessellation

Redoes parts of the tessellation for a Body *ET*, El

```
icode = EG_remakeTess(ego tess, int nobj, ego *facedg, double *parms);
icode = IG_remakeTess(I*8 tess, I*4 nobj, I*8  facedg, R*8     parms)
        tess.remakeTess(facedg, parms)
        remakeTess!(tess::Ego, facedg::Ego[], parms::Float[])
```

tess	the Tessellation Object to modify
nobj	number of Objects in the Face/Edge list
facedg	a pointer to a list of Face and/or Edge Objects from within the source Body used to create the Tessellation Object. First all specified Edges are rediscretized. Then any listed Face and the Faces touched by the retessellated Edges are retriangulated. Note that Quad Patches associated with Faces whose Edges were redone will be removed.
parms	a set of 3 parameters that drive the Edge discretization and the Face triangulation. The first is the maximum length of an Edge segment or triangle side (in physical space). A zero is flag that allows for any length. The second is a curvature-based value that looks locally at the deviation between the centroid of the discrete object and the underlying geometry. Any deviation larger than the input value will cause the tessellation to be enhanced in those regions. The third is the maximum interior dihedral angle (in degrees) between triangle facets (or Edge segment tangents for a WIREBODY tessellation), note that a zero ignores this phase.
icode	the integer return code

Redoes the discretization for specified Objects from within a Body Tessellation.

Places the tessellation from one Body onto another

```
  icode = EG_mapTessBody(ego tess, ego body, ego *newTess);
  icode = IG_mapTessBody(I*8 tess, I*8 body, I*8  newTess)
newTess = tess.mapTessBody(body)
newTess = mapTessBody(tess::Ego, body::Ego)
```

tess	the Body Tessellation Object used to create the tessellation on body
body	the Body Object (with a matching Topology) used to map the tessellation
newTess	the returned resultant Tessellation of body. The triangulation is simply copied but the $[u, v]$ and $[x, y, z]$ positions reflect the input Body (body).
icode	the integer return code

Maps the input discretization object to another Body Object. The topologies of the Body that created the input tessellation must match the topology of the body argument. The use of EG_mapBody (page 109) or EG_mapBody2 (page 110) can assist. Can be useful for finite differences.

Note: Invoking EG_moveEdgeVert (page 127), EG_deleteEdgeVert (page 127) and/or EG_insertEdgeVerts (page 128) in the source tessellation before calling this routine invalidates the ability of EG_mapTessBody to perform this function.

EGADS API – Tessellation

Provides a mapping for requested points

```
icode = EG_locateTessBody(const ego tess, int npts, const int *ifaces,
                          const double *uv, int *tris, double *weight);
icode = IG_locateTessBody(I*8       tess, I*4 npts, I*4        ifaces,
                          R*8           uv, I*4  tris, R*8     weight)
weight, tris = tess.locateTessBody(ifaces, uv, mapped=False)
weight, tris = locateTessBody(tess::Ego, ifaces::Int[],
                              uv::Float[]([]), mapped::Bool)
```

tess	the input Body Tessellation Object
npts	the number of input requests
ifaces	the face indices for each request; minus index refers to the use of a mapped Face index from EG_mapBody (page 109) & EG_mapTessBody (page 118) – npts in length
uv	the $[u, v]$ positions in the Face for each request – 2*npts in length
tris	the resultant 1-bias triangle index – npts in length if input as NULL then this function will perform mapped evaluations
weight	the vertex weights in the triangle that refer to the requested position (any negative weight indicates that the point was extrapolated) –or– the evaluated position based on the input uvs (when tris is NULL) 3*npts in length
icode	the integer return code

Provides the triangle and the vertex weights for each of the input requests or the evaluated positions in a mapped tessellation.

Gets the Edge discretization data *ET*, EI

```
icode = EG_getTessEdge(const ego tess, int eIndex, int *len,
                       const double **xyzs, const double **ts);
icode = IG_getTessEdge(I*8       tess, I*4 eIndex, I*4  len,
                       R*8            xyzs, R*8            ts)
xyzs, ts = tess.getTessEdge(eIndex)
xyzs, ts = getTessEdge(tess::Ego, eIndex::Int)
```

tess	the input Body Tessellation Object
eIndex	the Edge index (1 bias). The Edge Objects and number of Edges can be retrieved via EG_getBodyTopos (page 96) and/or EG_indexBodyTopo (page 97). A minus index refers to the use of a mapped (+) Edge index from applying the functions EG_mapBody (page 109) and EG_mapTessBody (page 118).
len	the returned number of vertices in the Edge discretization
xyzs	the returned pointer to the set of coordinate data – 3*len in length
ts	the returned pointer to the parameter values associated with each vertex – len in length
icode	the integer return code

Note: DEGENERATE Edges return 2 vertices (both the same coordinates of the single Node) and the *t* range in ts. This Edge will not be referenced in the associated Face tessellation.

EGADS API – Tessellation

Gets the Face triangulation data *ET*, El

```
icode = EG_getTessFace(const ego tess, int fIndex, int *len,
                       const double **xyz, const double **uv,
                       const int **ptype, const int **pindx, int *ntri,
                       const int **tris, const int **tric);
icode = IG_getTessFace(I*8       tess, I*4 fIndex, I*4  len,
                       R*8            xyz, R*8            uv,
                       I*4          ptype, I*4          pindx, I*4 *ntri,
                       I*4          tris, I*4          tric)
xyz, uv, ptype, pindx, tris, tric = tess.getTessFace(fIndex)
xyz, uv, ptype, pindx, tris, tric = getTessFace(tess::Ego, fIndx::Int)
```

tess	the input Body Tessellation Object
fIndex	the Face index (1 bias)
len	the returned number of vertices in the Face triangulation
xyz	the returned pointer to the set of coordinate data – 3*len in length
uv	the returned pointer to the parameters for each vertex – 2*len in length
ptype	returned pointer to the vertex type (-1 - internal, 0 - Node, > 0 Edge) – len in length
pindx	returned pointer to vertex index (-1 internal) – len in length
ntri	returned number of triangles
tris	returned pointer to triangle indices, 3 per triangle (1 bias) – 3*ntri in length
tric	returned pointer to neighbor information, 3 per triangle looking at opposing side: triangle (1-ntri), negative is Edge index for an external side – 3*ntri in length

EGADS API – Tessellation

Gets the Discrete Loop data *ET*, El

```
   icode = EG_getTessLoops(const ego tess, int fIndex, int *nloop,
                           const int **lIndices);
   icode = IG_getTessLoops(I*8       tess, I*4 fIndex, I*4  nloop,
                           I*4         lIndices)
lIndices = tess.getTessLoops(fIndex)
lIndices = getTessLoops(tess::Ego, fIndex::Int)
```

tess	the input Body Tessellation Object
fIndex	the Face index (1 bias). The Face Objects and number of Faces can be retrieved via EG_getBodyTopos and/or EG_indexBodyTopo.
nloop	the returned number of Loops in the Face triangulation
lIndeces	the returned pointer to a vector of the last index (bias 1) for each Loop – nloop in length. Notes:

1. all boundary vertices are listed first for any Face tessellation,
2. outer Loop data is ordered in the counter-clockwise direction, and
3. inner Loop(s) are ordered in the clockwise direction.

icode	the integer return code

Retrieves the data for the Loops associated with the discretization of a Face from a Body-based Tessellation Object.

Manually ask for quads *ET*, El

```
icode = EG_makeQuads(ego tess, double *qparms, int fIndex);
icode = IG_makeQuads(I*8 tess, R*4      qparms, I*4 fIndex)
        tess.makeQuads(qparms, fIndex)
        makeQuads!(tess::Ego, qparms::Float[], fIndex::Int)
```

tess — the input Body Tessellation Object

qparms — a set of 3 parameters that drive the Quadrilateral patching for the Face. Any may be set to zero to indicate the use of the default value:

- qparms[0] – Edge matching tolerance expressed as the deviation from an aligned dot product [*default* : 0.05]
- qparms[1] – Maximum quad *side ratio* point count to allow [*default* : 3.0]
- qparms[2] – Number of smoothing loops [*default* : 0.0]

fIndex — the Face index (1 bias)

icode — the integer return code

Creates Quadrilateral Patches for the indicated Face and updates the Body-based Tessellation Object (if possible).

Note: you may want to consider using EG_quadTess (page 116) instead.

Ask for Faces with Quad Patches *ET*, El

```
icode = EG_getTessQuads(ego tess, int *nface, int **fList);
icode = IG_getTessQuads(I*8 tess, I*4  nface, I*4   fList)
fList = tess.getTessQuads()
fList = getTessQuads(tess::Ego)
```

tess	the Body Tessellation Object
nface	the returned number of Faces with Quad patches
fList	the returned pointer the Face indices (1 bias) – nface in length (freeable) The Face Objects themselves can be retrieved via EG_getBodyTopos
icode	the integer return code

Returns a list of Face indices found in the Body-based Tessellation Object that has been successfully Quadded via EG_makeQuads – page 123.

Gets the Quad Face data *ET*, El

```
icode = EG_getQuads(const ego tess, int fIndex, int *len,
                    const double **xyz, const double **uv,
                    const int **ptype, const int **pindx, int *npatch);
icode = IG_getQuads(I*8       tess, I*4 fIndex, I*4  len,
                    R*8            xyz, R*8            uv,
                    I*4          ptype, I*4          pindx, I*4 *npatch)
xyz, uv, ptype, pindx, npatch = tess.getQuads(fIndex)
xyz, uv, ptype, pindx, npatch = getQuads(tess::Ego, fIndex::Int)
```

tess	the input Body Tessellation Object
fIndex	the Face index (1 bias)
len	the returned number of vertices in the Face triangulation
xyz	the returned pointer to the set of coordinate data – 3*len in length
uv	the returned pointer to the parameters for each vertex – 2*len in length
ptype	returned pointer to the vertex type (-1 - internal, 0 - Node, > 0 Edge) – len in length
pindx	returned pointer to vertex index (-1 internal) – len in length
npatch	returned number of patches
icode	the integer return code

Retrieves the data associated with the Quad-patching of a Face (using EG_makeQuads – page 123) in a Body-based Tessellation Object.

EGADS API – Tessellation

Gets the Quad Face patch data *ET*, El

```
icode = EG_getPatch(const ego tess, int fIndex, int pIndex,
                    int *n1, int *n2, const int **pvindex,
                    const int **pbounds);
icode = IG_getPatch(I*8       tess, I*4 fIndex, I*4 pIndex,
                    I*4  n1, I*4  n2, CPTR        pvindex,
                    CPTR         pbounds)
n1, n2, pvindex, pbounds = tess.getPatch(fIndex, pIndex)
n1, n2, pvindex, pbounds = getPatch(tess::Ego, fIndex::Int,
                                    pIndex::Int)
```

tess	the input Body Tessellation Object
fIndex	the Face index (1 bias)
pIndex	the Patch index (from 1 to npatch returned by EG_getQuads)
n1	the returned patch size in the first direction (indexed by i)
n2	the returned patch size in the second direction (indexed by j)
pvindex	the returned pointer to $n1 * n2$ indices that define the patch
pbounds	returned pointer to the neighbor bounding information for the patch. The first represents the segments at the base (j at base and increasing in i), the next is at the right (with i at max and j increasing). The third is the top (with j at max and i decreasing) and finally the left (i at min and j decreasing). $(2 * (n1 - 1) + 2 * (n2 - 1)$ in length

Retrieves the patch data associated with the Quad data on a Face (generated by EG_makeQuads – page 123) in a Body-based Tessellation Object.

EGADS API – Tessellation

Move the position of an Edge Vertex *ET*, El

```
icode = EG_moveEdgeVert(ego tess, int eIndex, int vIndex, double t);
icode = IG_moveEdgeVert(I*8 tess, I*4 eIndex, I*4 vIndex, R*8    t)
        tess.moveEdgeVert(eIndex, vIndex, t)
        moveEdgeVert!(tess::Ego, eIndex::Int, vIndex::Int, t::Float)
```

tess	the Body Tessellation Object (not on WIREBODIES)
eIndex	the Edge index (1 bias)
vIndex	the Vertex index in the Edge (2 to nVert-1)
t	the new parameter value on the Edge for the point

Note: Will invalidate the Quad patches on any Faces touching the Edge.

Deletes an Edge Vertex *ET*, El

```
icode = EG_deleteEdgeVert(ego tess, int eIndex, int vIndex, int dir);
icode = IG_deleteEdgeVert(I*8 tess, I*4 eIndex, I*4 vIndex, I*4 dir)
        tess.deleteEdgeVert(eIndex, vIndex, dir)
        deleteEdgeVert!(tess::Ego, eIndex::Int, vIndex::Int, dir::Int)
```

tess	the Body Tessellation Object (not on WIREBODIES)
eIndex	the Edge index (1 bias)
vIndex	the Vertex index in the Edge (2 to nVert-1)
dir	the direction to collapse any triangles (either -1 or 1)

Note: Will invalidate the Quad patches on any Faces touching the Edge.

EGADS API – Tessellation

Insert vertices on an Edge *ET*, El

```
icode = EG_insertEdgeVerts(ego tess, int eIndex, int vIndex, int len,
                           double *ts);
icode = IG_insertEdgeVerts(I*8 tess, I*4 eIndex, I*4 vIndex, I*4 len,
                           R*8      ts)
tess.insertEdgeVerts(eIndex, vIndex, ts)
insertEdgeVerts!(tess::Edge, eIndex::Int, vIndex::Int, ts::Float([]))
```

tess	the Body Tessellation Object (not on WIREBODIES)
eIndex	the Edge index (1 bias)
vIndex	the Vertex index in the Edge (2 to nVert-1)
len	the number of points to insert
ts	a vector of *t* values for the new points. Must be monotonically increasing and be greater than the *t* of vIndex and less than the *t* of vIndex+1.
icode	the integer return code

Note: Will invalidate the Quad patches on any Faces touching the Edge.

EGADS API – Tessellation

Open an existing Tessellation Object *ET*, El

```
icode = EG_openTessBody(ego tess);
icode = IG_openTessBody(I*8 tess)
        tess.openTessBody()
        openTessBody(tess::Ego)
```

tess the Tessellation Object to open

icode the integer return code

Opens an existing Tessellation Object for replacing Edge/Face discretizations.

Open a new (empty) Tessellation Object *ET*, El

```
icode = EG_initTessBody(ego body, ego *tess);
icode = IG_initTessBody(I*8 body, I*8  tess)
 tess = body.initTessBody()
 tess = initTessBody(body::Ego)
```

body the input object, may be any Body type

tess resultant empty Tessellation Object where each Edge in the BODY must be filled via a call to EG_setTessEdge (page 131) and each Face must be filled with invocations of EG_setTessFace (page 132). The Tessellation Object is considered open until all Edges have been set (for a WIREBODY), all Faces have been set (for other Body types) or EG_finishTess (page 134) is called.

icode the integer return code

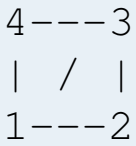
Status of a Tessellation Object *ET*, EI

```
icode = EG_statusTessBody(ego tess, ego *body, int *stat, int *npts);
icode = IG_statusTessBody(I*8 tess, I*8  body, I*4  stat, I*4  npts)
body, stat, icode, npts = tess.statusTessBody()
body, stat, icode, npts = statusTessBody(tess::Ego)
```

tess	the Tessellation Object to query
body	the returned associated Body Object
stat	the returned state of the tessellation: -1 – closed but warned, 0 – open, 1 – OK, 2 – displaced
npts	the returned number of global points in the tessellation (0 – open)
icode	the integer return code: EGADS_SUCCESS – complete, EGADS_OUTSIDE – still open

Note: Placing the attribute ".mixed" on tess before invoking this function allows for tri/quad (2 tris) tessellations. The type must be ATTRINT and the length is the number of Faces, where the values are the number of quads (triangle pairs) per Face. Single triangles are followed by triangle pairs for a Face with both triangle and quads.

Given quad 1 2 3 4 ==>
trias 1 2 3 and 1 3 4



EGADS API – Tessellation

Sets the Edge discretization data *ET*, El

```
icode = EG_setTessEdge(ego tess, int eIndex, int len,
                       const double *xyzs, const double *ts);
icode = IG_setTessEdge(I*8 tess, I*4 eIndex, I*4 len,
                       R*8           xyzs, R*8           ts)
tess.setTessEdge(eIndex, xyzs, ts)
setTessEdge!(tess::Ego, eIndex::Int, xyzs::Float[][], ts::Float[])
```

tess	the open Tessellation Object
eIndex	the Edge index (1 bias). The Edge Objects and number of Edges can be retrieved via EG_getBodyTopos and/or EG_indexBodyTopo. If this Edge already has assigned data, it is overwritten.
len	the number of vertices in the Edge discretization
xyzs	the pointer to the set of coordinate data – 3*len in length
ts	the pointer to the parameter values associated with each vertex – len in length
icode	the integer return code

Notes:

1. all vertices must be specified in increasing *t*
2. the coordinates for the first and last vertex MUST match the appropriate Node's coordinates
3. problems are reported to *Standard Out* regardless of the OutLevel

EGADS API – Tessellation

Sets the Face triangulation data 1/2 *ET*, EI

```
icode = EG_setTessFace(ego tess, int fIndex, int len,
                       const double *xyz, const double *uv,
                       int ntri, const int *tris);
icode = IG_setTessFace(I*8 tess, I*4 fIndex, I*4 len,
                       R*8           xyz, R*8           uv,
                       I*4 ntri, I*4        tris)
        tess.setTessFace(fIndex, xyz, uv, tris)
        setTessFace!(tess::Ego, fIndex::Int, xyz::Float[][],
                     uv::Float[][], tris::Int[][])
```

tess	the open Body Tessellation Object
fIndex	the Face index (1 bias). The Face Objects and number of Faces can be retrieved via EG_getBodyTopos and/or EG_indexBodyTopo. If this Face already has assigned data, it is overwritten.
len	the number of vertices in the Face triangulation
xyz	the pointer to the set of coordinate data – 3*len in length
uv	the pointer to the parameters for each vertex – 2*len in length
ntri	returned number of triangles
tris	the pointer to triangle indices, 3 per triangle (1 bias) – 3*ntri in length
icode	the integer return code

Sets the Face triangulation data 2/2 *ET*, EI

Notes:

1. All Edges associated with the Face must have been set
2. Any vertex associated with a Node or an Edge must use the exact coordinates specified by the Node or the Edge discretization
3. During the execution of EG_setTessFace the vertices that are input will go through renumbering. This is because there is an internal assumption that the first suite of coordinates represent the Edge tessellation ordered by the Loops found in the Face. This is usually fine, but there are circumstances that you may need to know the mapping, so that later you can find specific a specific vertex. This can be reverse engineered by maintaining the initial triangle list, calling EG_getTessFace – page 121 (after the invocation of EG_setTessFace) and using the triangles to construct the index mapping. To state it in another way: the triangle order is fixed but the list of vertices has been rearranged.
4. Problems are reported to *Standard Out* regardless of the OutLevel

Finish up and close an Open Tessellation Object *ET*, El

```
icode = EG_finishTess(ego tess, double *parms);
icode = IG_finishTess(I*8 tess, R*8     parms)
        tess.finishTess(parms)
        finishTess!(tess::Ego, parms::Float[])
```

tess — the Open Tessellation Object to close

parms — a set of 3 parameters that drive the Edge discretization and the Face triangulation. The first is the maximum length of an Edge segment or triangle side (in physical space). A zero is flag that allows for any length. The second is a curvature-based value that looks locally at the deviation between the centroid of the discrete object and the underlying geometry. Any deviation larger than the input value will cause the tessellation to be enhanced in those regions. The third is the maximum interior dihedral angle (in degrees) between triangle facets (or Edge segment tangents for a WIREBODY tessellation), note that a zero ignores this phase.

icode — the integer return code

Completes the discretization for unfilled entities found within the input Tessellation Object.

Note: an open Tessellation Object is created by EG_initTessBody (page 129) and can be partially filled via EG_setTessEdge (page 131) and/or EG_setTessFace (page 132) before this function is invoked.

EGADS API – Tessellation

Global Lookup *ET*, El

```
icode = EG_localToGlobal(const ego tess, int ind, int locl, int *gbl);
icode = IG_localToGlobal(I*8       tess, I*4 ind, I*4 locl, int  gbl)
  gbl = tess.localToGlobal(ind, locl)
  gbl = localToGlobal(tess::Ego, ind::Int, locl::Int)
```

tess	the closed Tessellation Object
ind	the topological index (1 bias) – 0 Node, (-) Edge, (+) Face
locl	the local (or Node) index
gbl	the returned global vertex index

Gets the vertex type and index *ET*, El

```
icode = EG_getGlobal(const ego tess, int global, int *pytpe,
                     int *pindex, double *xyz);
icode = IG_getGlobal(I*8       tess, I*4 global, I*4  ptype,
                     I*4  pindex, R*8     xyz)
ptype, pindex, xyz = tess.getGlobal(global)
ptype, pindex, xyz = getGlobal(tess::Ego, global::Int)
```

tess	the closed Tessellation Object
global	the global index (1 bias)
ptype	the point type (-) Face local index, (0) Node, (+) Edge local index
pindex	the point topological index (1 bias)
xyz	the filled (3 in length) coordinates at this global index (can be NULL)

Returns the Discrete Mass Properties dot

```
icode = EG_tessMassProps(const ego tess, double *props);
icode = IG_tessMassProps(I*8       tess, R*8     props)
volume, aeraOrLen, CG, I = tess.tessMassProps()
volume, aeraOrLen, CG, I = tessMassProps(tess::Ego)
```

tess	the Body Tessellation Object used to compute the Mass Properties
props	14 doubles filled reflecting Volume, Area (or Length), Center of Gravity (3) and the inertia matrix at CG (9)
icode	the integer return code

Computes and returns the physical and inertial properties of a Tessellation Object.

EGADS API – Tessellation

Write Tessellation to Disk – Deprecated

```
icode = EG_saveTess(ego tess, const char *filename);
icode = IG_saveTess(I*8 tess, C**          filename)
```

tess	the closed Tessellation Object
filename	the filename (including extension)
icode	the integer return code

The extension can be anything, but it is suggested that ".eto" (EGADS Tessellation Object) be used.

Read Tessellation from Disk – Deprecated

```
icode = EG_loadTess(ego body, const char *filename, ego *tess);
icode = IG_loadTess(I*8 body, C**          filename, I*8  tess)
```

body	the Body Object to attach the tessellation from the file
filename	the filename (including extension) to load
tess	the returned Tessellation Object
icode	the integer return code

Perform the Solid Boolean Operations – Deprecated

```
icode = EG_solidBoolean(const ego src, const ego tool, int oper,
                        ego *model);
icode = IG_solidBoolean(I*8       src, I*8       tool, I*4 oper,
                        I*8  model)
```

src	the source SOLIDBODY Body Object
tool	the tool object: either a SOLIDBODY for all operators –or– a FACE/FACEBODY for SUBRTRACTION
oper	one of: INTERSECTION, SUBTRACTION, FUSION
model	the resultant Model Object (this is because there may be multiple bodies from either the SUBTRACTION or INTERSECTION operation).
icode	the integer return code

Performs the Solid Boolean Operations (SBOs) on the source Body Object (that has the type SOLIDBODY). The tool Object types depend on the operation. This supports Intersection, Subtraction and Union.

Note: This may be called with src being a Model Object. In this case tool may be a SOLIDBODY for Intersection/Subtraction or a FACE/FACEBODY for Fusion. The input Model Object may contain anything, but must not have duplicate topology.

EGADS API – Top-Down Build Functions

Perform the Boolean Operations

```
icode = EG_generalBoolean(ego src, ego tool, int oper, double tol,
                          ego *model);
icode = IG_generalBoolean(I*8 src, I*8 tool, I*4 oper, R*8    tol,
                          I*8  model)
model = src.generalBoolean(tool, oper, tol=0.0)
model = generalBoolean(src::Ego, tool::Ego, oper::Int; tol::Real)
```

src	the source in the form of a Model or Body Object
tool	the tool in the form of a Model or Body Object
oper	one of: INTERSECTION, SUBTRACTION, FUSION, SPLITTER
tol	the tolerance applied when performing the operation. If set to 0.0, the minimum tolerance is applied
model	the returned resultant Model Object (this is because there may be multiple bodies from either the SUBTRACTION or INTERSECTION operation).
icode	the integer return code

Performs the Boolean Operations on the source Body Object(s). The tool Body Object(s) are applied depending on the operation. This supports Intersection, Splitter, Subtraction and Union.

Note: The Body Object(s) for src and tool can be of any type and the results depend on the operation.

EGADS API – Top-Down Build Functions

Perform a Union on Sheet Bodies

```
icode = EG_fuseSheets(ego src, ego tool, ego *sheet);
icode = IG_fuseSheets(I*8 src, I*8 tool, I*8  sheet)
sheet = src.generalBoolean(tool)
sheet = fuseSheets(src::Ego, tool::Ego)
```

src	the source Sheet Body Object
tool	the tool Sheet Body Object
sheet	the returned resultant Body Object (`mtype` is SHEETBODY).
icode	the integer return code

Fuses (unions) two Sheet Body Objects resulting in a single Sheet Body Object.

EGADS API – Top-Down Build Functions

Provide the Intersection

```
icode = EG_intersection(ego src, ego tool, int *nEdge, ego **pairs,
                        ego *model);
icode = IG_intersection(I*8 src, I*8 tool, I*4  nEdge, I*8   pairs,
                        I*8  model)
pairs, model = src.intersection(tool)
pairs, model = intersection(src::Ego, tool::Ego)
```

src	the source Body (FACEBODY/SHEETBODY/SOLIDBODY) Object
tool	the FACE/FACEBODY/SHEETBODY/SOLIDBODY tool Object
nEdge	the returned number of Edge Objects created
pairs	the returned pointer to Face/Edge Object pairs – 2*nEdge in len (freeable) can be NULL (if you don't need the data – the Edge Objects are in model)
model	the resultant Model Object which contains the set of WIREBODY Objects (this is because there may be multiple Loop Objects as a result of the operation). Deleting model invalidates the data in pairs.
icode	the integer return code

Intersects the source Body Object with the tool Object and returns the intersection fragments.

Notes: 1) The new Edge Objects have the attributes of the Face Object in src cut for that Edge.

2) If the total number of Edges in model does not match nEdge there has been an intersection that is coincident with existing Edge(s). model must be parsed to determine what Edge(s) require splitting. EG_imprintBody will probably not currently work under these circumstances.

EGADS API – Top-Down Build Functions

Scribe a Body

```
 icode = EG_imprintBody(ego src, int nObj, ego *pairs, ego *result);
 icode = IG_imprintBody(I*8 src, I*4 nObj, I*8  pairs, I*8  result)
result = src.imprintBody(pairs)
result = imprintBody(src::Ego, pairs::Ego[][])
```

src	the source Body Object
nObj	the number of Object pairs to imprint
pairs	pointer to a list of Face/Edge and/or Face/Loop Object pairs to scribe 2*nObj in len – can be the output from EG_intersection.
result	the returned resultant Body Object (with the same type as src), though the splitting of Face Body Object results in a SHEETBODY
icode	the integer return code

Imprints Edge/Loop Objects on the source Body Object (that has the type SOLIDBODY, SHEETBODY or FACEBODY). The Edge/Loop Objects are paired with the Faces in the source that will be scribed.

Note: Under rare circumstance this may fail and return the indication of success [especially after seeing the message: *EGADS Info: splitBody = xx – using OpenCASCADE (EG_imprintBody)!*].
If appropriate, you may want to consider using the SPLITTER operation of EG_generalBoolean.

EGADS API – Top-Down Build Functions

Fillet a Body

```
icode = EG_filletBody(ego src, int nEdge, ego *edges, double radius,
                      ego *result, int **maps);
icode = IG_filletBody(I*8 src, I*4 nEdge, I*8  edges, R*8    radius,
                      I*8  result, CPTR  maps)
result, map = src.filletBody(edges, radius)
result, map = filletBody(src::Ego, edges::Ego[], radius::Float)
```

src	the source Body Object
nEdge	the number of Edge Objects to fillet
edges	pointer to a list of Edges to fillet – nEdge in len
radius	the radius of the fillets created
result	the resultant Body Object (with the same type as src)
maps	the returned pointer to a list of Face mappings (in result) which includes operations (see page 13) and an index in src where the Face originated – 2*(number of Faces in result) in length (freeable)
icode	the integer return code

Fillets the Edges on the source Body Object (that has the type SOLIDBODY or SHEETBODY).

EGADS API – Top-Down Build Functions

Chamfer a Body

```
icode = EG_chamferBody(ego src, int nEdge, ego *edges, ego *faces,
                       double dis1, double dis2, ego *result,
                       int **maps);
icode = IG_chamferBody(I*8 src, I*4 nEdge, I*8  edges, I*8  faces,
                       R*8    dis1, R*8    dis2, I*8  result,
                       CPTR  maps)
result, map = src.chamferBody(edges, faces, dis1, dis2)
result, map = chamferBody(src::Ego, edges::Ego[], faces::Ego[],
                          dis1::Float, dis2::Float)
```

src	the source Body Object
nEdge	the number of Edge Objects to chamfer
edges	pointer to a list of Edges to chamfer – nEdge in len
faces	pointer to a list of Face Objects to to measure dis1 from – nEdge in len
dis1	the distance from the Face Object to chamfer
dis2	the distance from the *other* Face Object to chamfer
result	the resultant Body Object (with the same type as src)
maps	the returned pointer to a list of Face mappings (in result) which includes operations (see page 13) and an index in src where the Face originated – 2*(number of Faces in result) in length (freeable)
icode	the integer return code

Chamfers the Edges on the source Body Object (that has the type SOLIDBODY or SHEETBODY).

EGADS API – Top-Down Build Functions

Hollow a Body

```
icode = EG_hollowBody(ego src,  int nFace, ego *faces, double off,
                      int join, ego *result, int **maps);
icode = IG_hollowBody(I*8 src,  I*4 nFace, I*8  faces, R*8    off,
                      I*4 join, I*8  result, CPTR  maps)
result, map = src.hollowBody(faces, off, join)
result, map = hollowBody(src::Ego, faces::Ego([]), off::Float,
                         join::Int)
```

src	the source Body Object (SOLIDBODY, SHEETBODY, FACEBODY or FACE*)
nFace	the number of Face Objects to remove (0 performs an *offset*)
faces	pointer to a list of FACE objects to remove – nFace in len
off	the wall thickness (or offset) of the result
join	0 – fillet-like corners, 1 – expanded corners
result	the resultant Body Object
maps	the returned pointer to a list of Face mappings (in result) which includes operations (see page 13) and an index in src where the Face originated – 2*(number of Faces in result) in length (freeable)
icode	the integer return code

A hollowed *solid* is built from an initial SOLIDBODY Object and a set of Faces that bound the *solid*. These Faces are removed and the remaining become the walls of the *hollowed solid* with the specified thickness. If there are no Faces specified then the Body is *offset* by off (which can be negative).

* Note: If src is a Face, then faces should be a list of Edges and the result will be a Face Object. maps in this case is not filled.

EGADS API – Top-Down Build Functions

Revolve to create a Body

```
 icode = EG_rotate(ego src, double angle, double *axis, ego *result);
 icode = IG_rorate(I*8 src, R*8    angle, R*8     axis, I*8  result)
result = src.rotate(angle, axis)
result = rotate(src::Ego, angle::Float, axis::Float[]([]))
```

src	the source Body Object (not SHEETBODY or SOLIDBODY)
angle	the angle to rotate the object through [0-360 Degrees]
axis	pointer to a point (on the axis) and a direction (6 in length)
result	the returned resultant Body Object (type is one higher than src)
icode	the integer return code

Revolves the source Object about the axis through the angle specified. If the Object is either a Loop or WIREBODY the result is a SHEETBODY. If the source is either a Face or FACEBODY then the returned Body Object is a SOLIDBODY.

EGADS API – Top-Down Build Functions

Extrude to create a Body dot

```
 icode = EG_extrude(ego src, double dist, double *dir, ego *result);
 icode = IG_extrude(I*8 src, R*8    dist, R*8      dir, I*8  result)
result = src.extrude(dist, dir)
result = extrude(src::Ego, dist::Float, dir::Float[])
```

src	the source Body Object (not SHEETBODY or SOLIDBODY)
dist	the distance to extrude
dir	pointer to the vector that is the extrude direction (3 in length)
result	the returned resultant Body Object (type is one higher than src)
icode	the integer return code

Extrudes the source Object through the distance and direction specified. If the Object is either a Loop or WIREBODY the result is a SHEETBODY. If the source is either a Face or FACEBODY then the returned Body Object is a SOLIDBODY.

EGADS API – Top-Down Build Functions

Sweep to create a Body

```
 icode = EG_sweep(ego src, ego spine, int mode, ego *result);
 icode = IG_sweep(I*8 src, I*8 spine, I*4 mode, I*8  result)
result = src.sweep(spine, mode)
result = sweep(src::Ego, spine::Ego, mode::Int)
```

src	the source Body Object (not SHEETBODY or SOLIDBODY)
spine	the Object used as guide curve segment(s) to sweep the source through
mode	sweep mode:

0	Corrected Frenet	5	Guide AC
1	Fixed	6	Guide Plan
2	Frenet	7	Guide AC With Contact
3	Constant Normal	8	Guide Plan With Contact
4	Darboux	9	Discrete Trihedron

result	the returned resultant Body Object (type is one higher than src)
icode	the integer return code

Sweeps the source Object through the "spine" specified. The spine can be either an Edge, Loop or WIREBODY Object. If the source Object is either a Loop or WIREBODY the result is a SHEETBODY. If the source is either a Face or FACEBODY then the returned Object is a SOLIDBODY.

Note: this does not aways work as expected...

EGADS API – Top-Down Build Functions

Lofts through sections to create a Body – Deprecated

```
icode = EG_loft(int nSection, ego *sections, int option, ego *result);
icode = IG_loft(I*4 nSection, I*8  sections, I*4 option, I*8  result)
```

nSection	the number of Sections in the Loft Operation
sections	pointer to a list of WIREBODY or Loop Objects to Loft – nSection in len the first and last can be Node Objects
option	bit flag that controls the loft: 1 – SOLIDBODY result (default is SHEETBODY) 2 – Ruled (linear) Loft (default is smooth)
result	the resultant Body Object
icode	the integer return code

Lofts the input Objects to create a Body Object (that has the type SOLIDBODY or SHEETBODY).

Please use either EG_blend (page 151) or EG_ruled (page 150).

EGADS API – Top-Down Build Functions

Linearly lofts through sections to create a Body dot

```
 icode = EG_ruled(int nSection, ego *sections, ego *result);
 icode = IG_ruled(I*4 nSection, I*8  sections, I*8  result)
result = egads.ruled(sections)
result = ruled(sections::Ego)
```

nSection	the number of Sections in the *rule* Operation note: interior repeated sections are ignored
sections	a list of FACEBODY, Face, WIREBODY or Loop Objects (nSection in len) FACEBODY/Faces must have only a single Loop; all or the first and last sections can be Nodes; if the first/last are Nodes and/or FACEBODY/Faces (and the internal sections are CLOSED) the result will be a SOLIDBODY otherwise it will be a SHEETBODY; if the first and last sections contain equivalent Loops (and all sections are CLOSED) a periodic (torus-like) SOLIDBODY is created
result	the resultant Body Object
icode	the integer return code

Produces a Body Object (that has the type SOLIDBODY or SHEETBODY) that goes through the sections by *ruling* surfaces between each. All sections must have the same number of Edges (except for Nodes) and the Edge order in each is used to specify the connectivity. An exception is when the attribute ".multiNode" is found on Nodes in the Loop, which needs to be numeric and indicates the multiplicity of the Node [creating Degenerate Edge(s) in the result]. If this is the case, the number of Edges and the sum of the Node multiplicities must be the same for each section. There is a special case when the attributed Node is the first in the Loop and the Loop is closed: a second numeric value is required in the attribute where this one indicates the the start – 0 is all degenerates are at the start, and if the number of multiples then the start is the Edge itself, where the degenerates end up at the end of the Loop.

Note: for both EG_blend and EG_ruled: all Loops must have their Edges ordered in a CCW (counterclockwise) manner.

EGADS API – Top-Down Build Functions

Lofts through sections to create a Body dot

```
 icode = EG_blend(int nSection, ego *sections, double *rc1,
                  double *rc2, ego *result);
 icode = IG_blend(I*4 nSection, I*8  sections, R*8     rc1,
                  R*8     rc2, I*8  result)
result = egads.blend(sections, rc1=None, rc2=None)
result = blend(sections::Ego[]; rc1::Float[], rc2::Float[])
```

nSection	the number of Sections in the *blend* Operation
sections	a list of FACEBODY, Face, WIREBODY or Loop Objects (nSection in len) FACEBODY/Faces must have only a single Loop; all or the first and last sections can be Nodes; if the first/last are Nodes and/or FACEBODY/Faces (and the internal sections are CLOSED) the result will be a SOLIDBODY otherwise it will be a SHEETBODY; if the first and last sections contain equivalent Loops (and all sections are CLOSED) a periodic (C^0 at closure) SOLIDBODY is created. Interior sections are C^2 and can be repeated once† for C^1 or twice for C^0
rc1	specifies treatment‡ at the first section (or NULL for no treatment)
rc2	specifies treatment‡ at the last section (or NULL for no treatment)
result	the resultant Body Object

Lofts the input Objects to create a Body Object (that has the type SOLIDBODY or SHEETBODY). Cubic BSplines are used. All sections must have the same number of Edges (except for single Nodes) and the Edge order in each (in a CCW manner) is used to set the connectivity.

† section attribute `.C1side` set to "fwd" or "rev" overrides the default side to compute the C^1 tangency.

‡ for Nodes – elliptical treatment (8 in length): radius of curvature1, unit dir, radius of curvature2, orthogonal dir (nSection must be at least 3 or 4 for treatments at both ends); for other sections – setting tangency (4 in length): magnitude, unit direction; for Faces with 2 or 3 Edges in the Loop – make a *Wing Tip-like* cap: zero, growthFactor (length of 2).

Initialize *Effective Topology* Body *ET*

```
icode = EG_initEBody(ego tess, double angle, ego *ebody);
icode = IG_initEBody(I*8 tess, R*8    angle, I*8  ebody)
ebody = tess.initEBody(angle)
ebody = initEBody(tess::Ego, angle::Float)
```

tess	the input Solid or Sheet Body Tessellation Object (can be quite coarse)
angle	angle used to determine if Nodes on open Edges of Sheet Bodies can be removed. The dot of the tangents at the Node is compared to this angle (in degrees). If the dot is greater than the angle, the Node does not disappear. The angle is also used to test Edges to see if they can be removed. Edges with normals on both trimmed Faces showing deviations greater than the input angle will not disappear. Valid range 0.0 to 90.0 and should be closer to zero.
ebody	the resultant Open *Effective Topology* Body Object
icode	the integer return code

Takes as input a Body Tessellation Object and returns an Open EBody fully initialized with *Effective Objects* (that may only contain a single *non-effective* object). EEdges are automatically merged where possible (removing Nodes that touch 2 Edges, unless degenerate or marked as ".Keep"). The tessellation is used (and required) in order that single UV space be constructed for EFaces.

Construct EFaces using an Attribute *ET*

```
 icode = EG_makeAttrEFaces(ego ebody, const char *attrName,
                           int *neface, ego **efaces);
 icode = IG_makeAttrEFaces(I*8 ebody, C**         attrName,
                           I*4  neface, I*8   efaces)
efaces = ebody.makeAttrEFaces(attrName)
efaces = makeAttrEFaces(ebody::Ego, attrName::String)
```

ebody	the input Open *Effective Topology* Body Object
attrName	the attribute name used to collect Faces into an EFaces. The attribute value(s) are then matched to make the collections.
neface	the returned number of constructed EFaces
efaces	the returned pointer to a list of EFaces constructed (freeable) – may be NULL
icode	the integer return code

Modifies the EBody by finding "free" Faces (a single Face in an EFace) with attrName and the same attribute value(s), thus making a collection of EFaces. All attributes matching in the collection of Faces are moved to the EFace(s) (at a minimum attrName will persist) unless in "Full Attribute" mode, which then performs attribute merging. This function returns the number of EFaces possibly constructed (neface). The *UVbox* can be retrieved via calls to either `EG_getTopology` (page 90) or `EG_getRange` (page 81) with the returned appropriate efaces.

Note: triangulations must *touch* to be within an EFace.

Construct an EFace *ET*

```
icode = EG_makeEFace(ego ebody, int nface, ego *faces, ego *eface);
icode = IG_makeEFace(I*8 ebody, I*4 nface, I*8  faces, I*8  eface)
eface = ebody.makeEFace(faces)
eface = makeEFace(ebody::Ego, faces::Ego([]))
```

ebody the input Open *Effective Topology* Body Object
nface the number of Face Objects in faces
faces the list of Face Objects used to make eface (nface in length)
eface the returned constructed EFace Object now in ebody
icode the integer return code

Modifies the EBody by removing the nface "free" Faces and constructing a single eface (returned for convenience – the ebody is updated). All attributes matching in faces are moved to eface unless the "Full Attribution" mode is in place. This constructs a single UV for the faces. The *UVbox* can be retrieved via calls to EG_getTopology (page 90) or EG_getRange (page 81) with eface.

Finish an EBody *ET*

```
icode = EG_finishEBody(ego ebody);
icode = IG_finishEBody(I*8 ebody)
        ebody.finishEBody()
        finishEBody!(ebody::Ego)
```

ebody the input Open *Effective Topology* Body Object that will be Closed

Parameter/Object Lookup *ET*, El

```
icode = EG_effectiveMap(ego eobj, double *eparam, ego *obj,
                        double *param);
icode = IG_effectiveMap(I*8 eobj, R*8     eparam, I*8  obj,
                        R*8     param)
obj, param = eobj.effectiveMap(eparam)
obj, param = effectiveMap(eobj::Ego, eparam::Float([]))
```

eobj	the input *Effective Topology* Object (either EEdge or EFace)
eparam	t for EEdges / the $[u, v]$ for an EFace
obj	the returned source Object in the Body
param	the returned t for an Edge / the returned $[u, v]$ for the Face
icode	the integer return code

Returns the evaluated location in the BRep for the *Effective Topology* entity.

Returns details of an EEdge *ET*, EI

```
icode = EG_effectiveEdgeList(ego eedge, int *nedge, ego **edges,
                             int **senses, double **tstart);
icode = IG_effectiveEdgeList(I*8 eedge, I*4  nedge, I*8   edges,
                             I*4   senses, R*8      tstart)
edges, senses, tstart = eedge.effectiveEdgeList()
edges, senses, tstart = effectiveEdgeList(eedge::Ego)
```

eedge	the *Effective Topology* Edge Object
nedge	the returned number of Edges in edge and others
edges	the returned pointer to a list of Edges – nedge in length (freeable)
senses	the returned pointer to a list of senses – nedge in length (freeable)
tstart	the returned pointer to a list of t starting values – nedge in length (freeable)
icode	the integer return code

Returns the list of Edge entities in the source Body that make up the EEdge. A pointer to an integer list of senses for each Edge is returned as well as the starting t value in the EEdge (remember that the t will go in the opposite direction in the Edge if the sense is SREVERSE).

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