

CGNS/SIDS proposal for extensions

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Implementation of cubic elements for unstructured zones

The proposal is an extension of the element structure definition (*Elements_t*) for unstructured zones. We propose to add cubic elements to *ElementType*. This extension can enhance the performance of CGNS in handling high-order (≥ 2) elements which are widely used in high-order CFD simulations. Moreover, this extension can further strengthen the capability of CGNS on accurate presentation of complex geometry, especially when a coarse grid is provided.

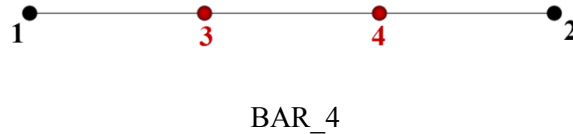
The new cubic element types proposed are summarized as follows.

Dimensionality of the Element	Shape	Cubic Interpolation
1-D	Line	BAR_4
2-D	Triangle	TRI_9, TRI_10
	Quadrangle	QUAD_12, QUAD_16
3-D	Tetrahedron	TETRA_20
	Pyramid	PYRA_29, PYRA_30
	Pentahedron	PENTA_38, PENTA_40
	Hexahedron	HEXA_56, HEXA_64

The element numbering convention is specified as follows.

Note that ‘N’ stands for grid point identification number. ‘E’ indicates edge identification number. A negative edge means that the edge is used in its reverse direction. ‘F’ stands for face identification number.

1. 1-D Element

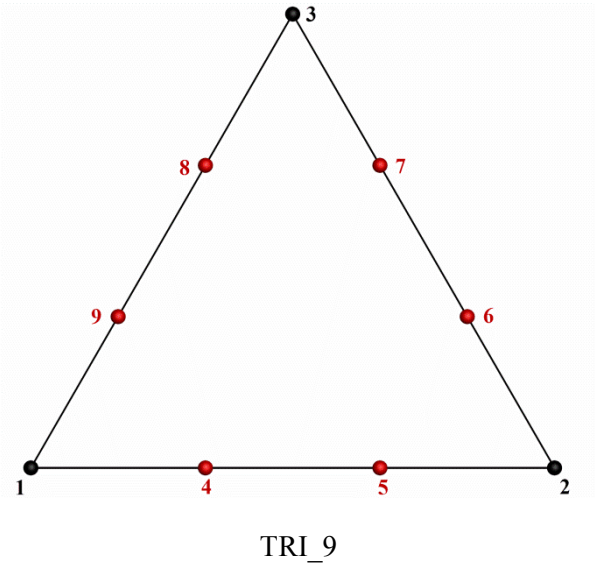


Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N3,N4

2. 2-D (Surface) Element

2.1 Triangular Element

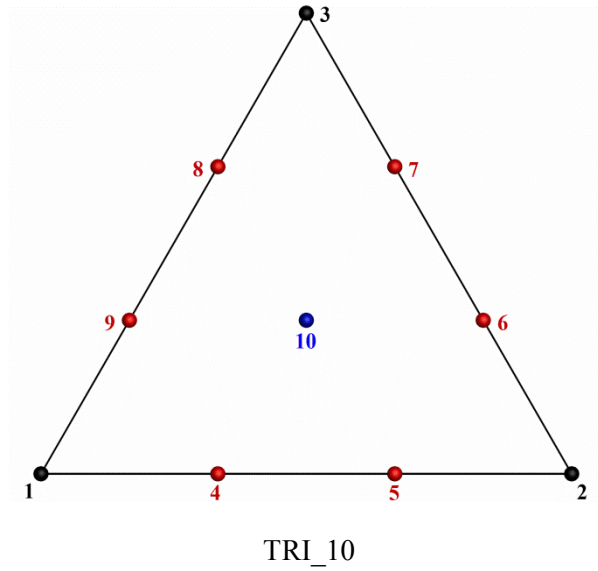


Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N4,N5
E2	N2,N3	N6,N7
E3	N3,N1	N8,N9

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Oriented edges
F1	N1,N2,N3	N4,N5,N6,N7,N8,N9	E1,E2,E3



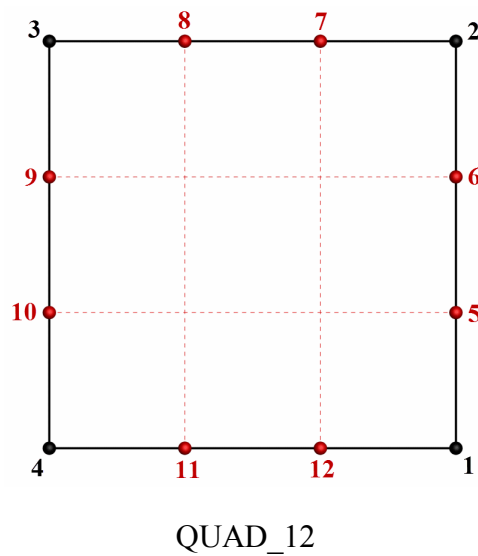
Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N4,N5
E2	N2,N3	N6,N7
E3	N3,N1	N8,N9

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N2,N3	N4,N5,N6,N7,N8,N9	N10	E1,E2,E3

2.2 Quadrilateral Element

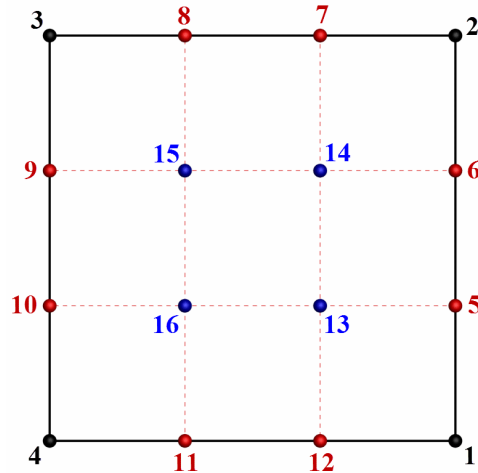


Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N5,N6
E2	N2,N3	N7,N8
E3	N3,N4	N9,N10
E4	N4,N1	N11,N12

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Oriented edges
F1	N1,N2,N3,N4	N5,N6,N7,N8,N9, N10,N11,N12	E1,E2,E3,E4



QUAD_16

Edge Definition

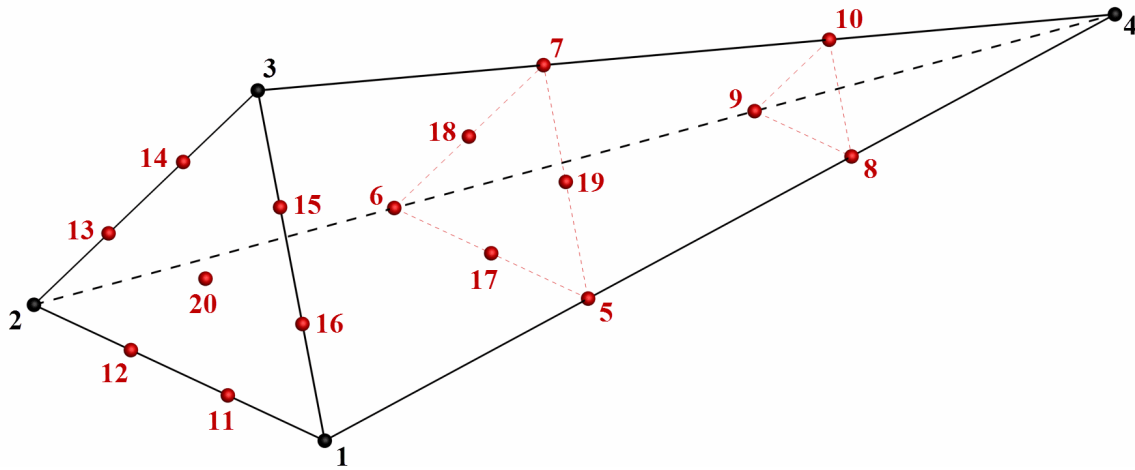
Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N5,N6
E2	N2,N3	N7,N8
E3	N3,N4	N9,N10
E4	N4,N1	N11,N12

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N2,N3,N4	N5,N6,N7,N8,N9, N10,N11,N12	N13,N14,N15, N16	E1,E2,E3

3. 3-D (Volume) Element

3.1 Tetrahedral Element



TETRA_20

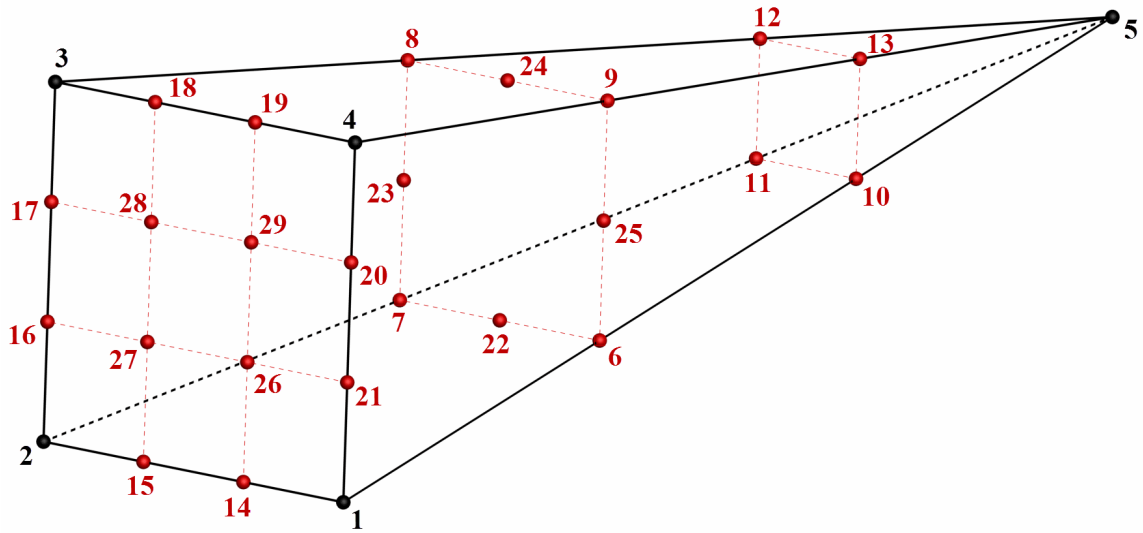
Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N11,N12
E2	N2,N3	N13,N14
E3	N3,N1	N15,N16
E4	N1,N4	N5,N8
E5	N2,N4	N6,N9
E6	N3,N4	N7,N10

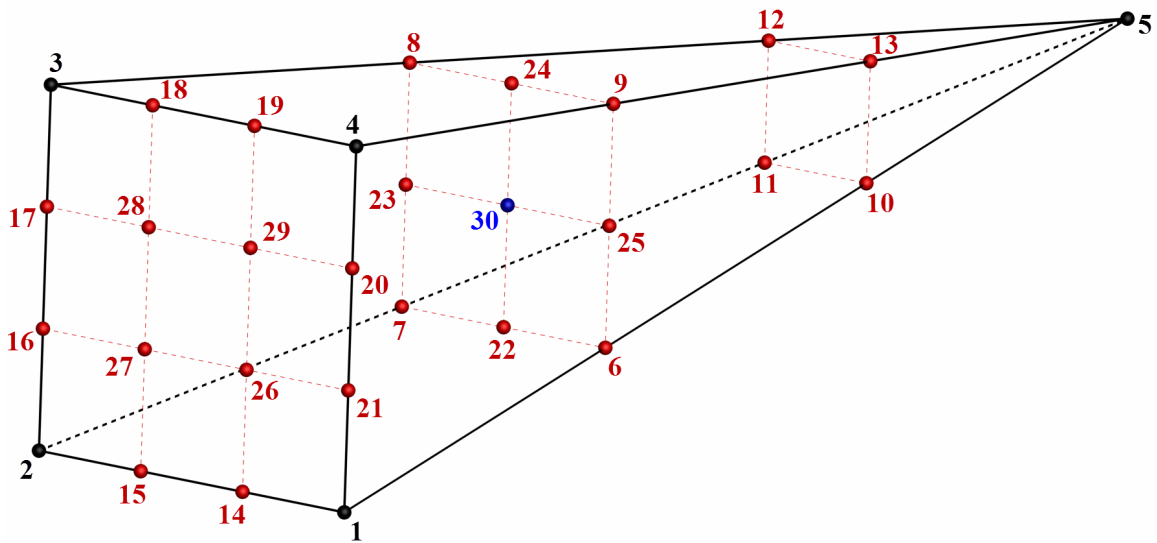
Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N3,N2	N16,N15,N14,N13,N12,N11	N20	-E3,-E2,-E1
F2	N1,N2,N4	N11,N12,N6,N9,N8,N5	N17	E1,E5,-E4
F3	N2,N3,N4	N13,N14,N7,N10,N9,N6	N18	E2,E6,-E5
F4	N3,N1,N4	N15,N16,N5,N8,N10,N7	N19	E3,E4,-E6

3.2 Pyramid Element



PYRA_29



PYRA_30

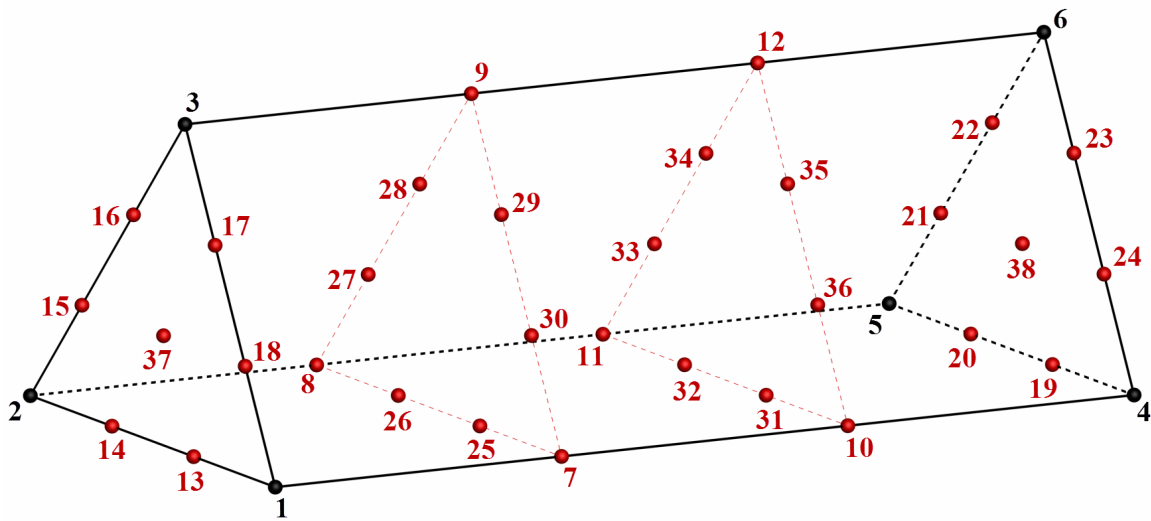
Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N14,N15
E2	N2,N3	N16,N17
E3	N3,N4	N18,N19
E4	N4,N1	N20,N21
E5	N1,N5	N6,N10
E6	N2,N5	N7,N11
E7	N3,N5	N8,N12
E8	N4,N5	N9,N13

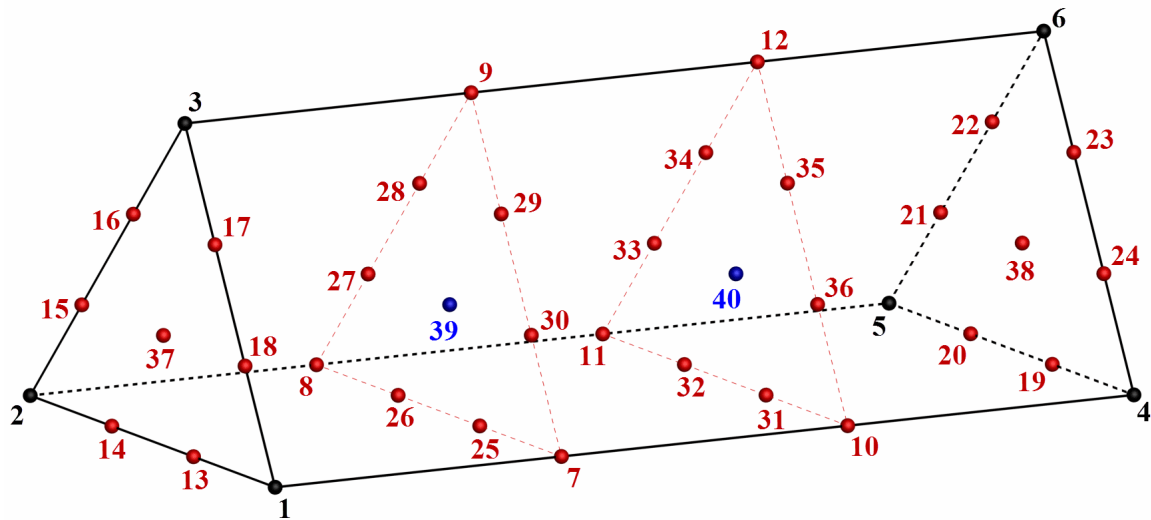
Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N4,N3,N2	N21,N20,N19,N18,N17, N16,N15,N14	N26,N29,N28, N27	-E4,-E3,-E2,-E1
F2	N1,N2,N5	N14,N15,N7,N11,N10,N6	N22	E1,E6,-E5
F3	N2,N3,N5	N16,N17,N8,N12,N11,N7	N23	E2,E7,-E6
F4	N3,N4,N5	N18,N19,N9,N13,N12,N8	N24	E3,E8,-E7
F5	N4,N1,N5	N20,N21,N6,N10,N13,N9	N25	E4,E5,-E8

3.3 Pentahedral Element



PENTA_38



PENTA_40

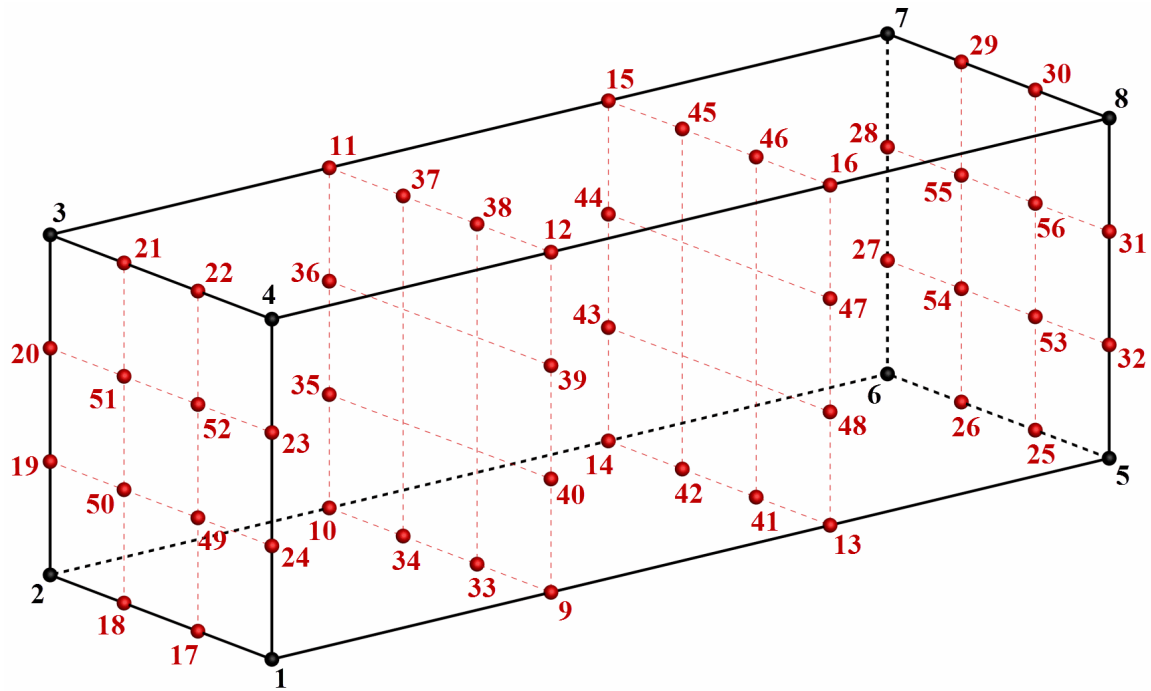
Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N13,N14
E2	N2,N3	N15,N16
E3	N3,N1	N17,N18
E4	N1,N4	N7,N10
E5	N2,N5	N8,N11
E6	N3,N6	N9,N12
E7	N4,N5	N19,N20
E8	N5,N6	N21,N22
E9	N6,N4	N23,N24

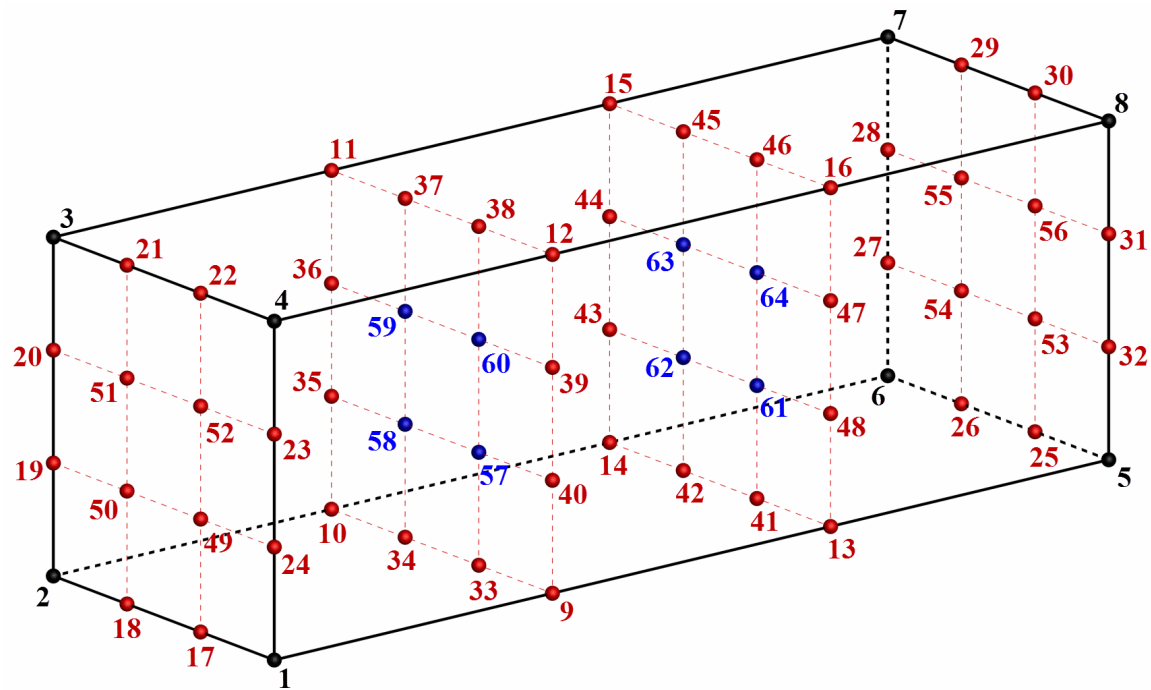
Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N2,N5,N4	N13,N14,N8,N11,N20, N19,N10,N7	N25,N26,N32, N31	E1,E5,-E7,-E4
F2	N2,N3,N6,N5	N15,N16,N9,N12,N22, N21,N11,N8	N27,N28,N34, N33	E2,E6,-E8,-E5
F3	N3,N1,N4,N6	N17,N18,N7,N10,N24, N23,N12,N9	N29,N30,N36, N35	E3,E4,-E9,-E6
F4	N1,N3,N2	N18,N17,N16,N15,N14, N13	N37	-E3,-E2,-E1
F5	N4,N5,N6	N24,N23,N22,N21,N20, N19	N38	E7,E8,E9

3.4 Hexahedral Element



HEXA_56



HEXA_64

Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N17,N18

E2	N2,N3	N19,N20
E3	N3,N4	N21,N22
E4	N4,N1	N23,N24
E5	N1,N5	N9,N13
E6	N2,N6	N10,N14
E7	N3,N7	N11,N15
E8	N4,N8	N12,N16
E9	N5,N6	N25,N26
E10	N6,N7	N27,N28
E11	N7,N8	N29,N30
E12	N8,N5	N31,N32

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N4,N3,N2	N24,N23,N22,N21,N20, N19,N18,N17	N49,N52,N51, N50	-E4,-E3,-E2,-E1
F2	N1,N2,N6,N5	N17,N18,N10,N14,N26, N25,N13,N9	N33,N34,N42, N41	E1,E6,-E9,-E5
F3	N2,N3,N7,N6	N19,N20,N11,N15,N28, N27,N14,N10	N35,N36,N44, N43	E2,E7,-E10,-E6
F4	N3,N4,N8,N7	N21,N22,N12,N16,N30, N29,N15,N11	N37,N38,N46, N45	E3,E8,-E11,-E7
F5	N1,N5,N8,N4	N9,N13,N32,N31,N16, N12,N23,N24	N40,N48,N47, N39	E5,-E12,-E8,E4
F6	N5,N6,N7,N8	N25,N26,N27,N28,N29, N30,N31,N32	N53,N54,N55, N56	E9,E10,E11,E12