

CGNS/SIDS proposal for extensions

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Implementation of quartic elements for unstructured zones

The proposal is an extension of the element structure definition (*Elements_t*) for unstructured zones. We propose to add quartic 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 quartic element types proposed are summarized as follows.

Dimensionality of the Element	Shape	Cubic Interpolation
1-D	Line	BAR_5
2-D	Triangle	TRI_12, TRI_15
	Quadrangle	QUAD_P4_16*, QUAD_25
3-D	Tetrahedron	TETRA_22, TETRA_34, TETRA_35
	Pyramid	PYRA_P4_29*, PYRA_50, PYRA_55
	Pentahedron	PENTA_33, PENTA_66, PENTA_75
	Hexahedron	HEXA_44, HEXA_98, HEXA_125

*: 'P4' is assigned to distinguish the corresponding cubic elements of the same number of points.

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



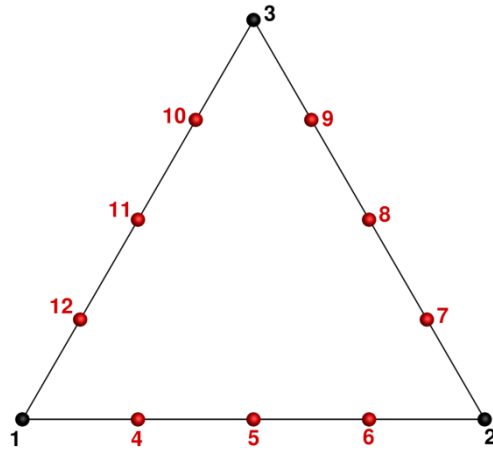
BAR_5

Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N3,N4,N5

2. 2-D (Surface) Element

2.1 Triangular Element



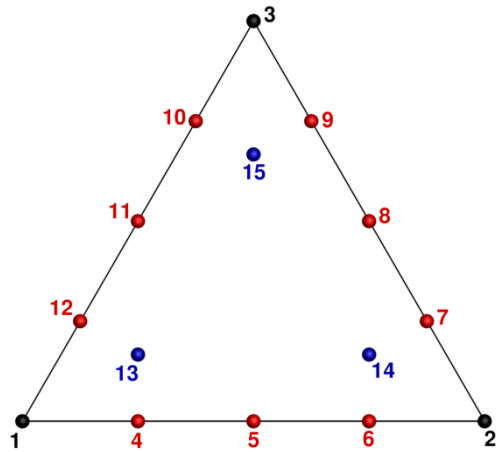
TRI_12

Edge Definition

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



TRI_15

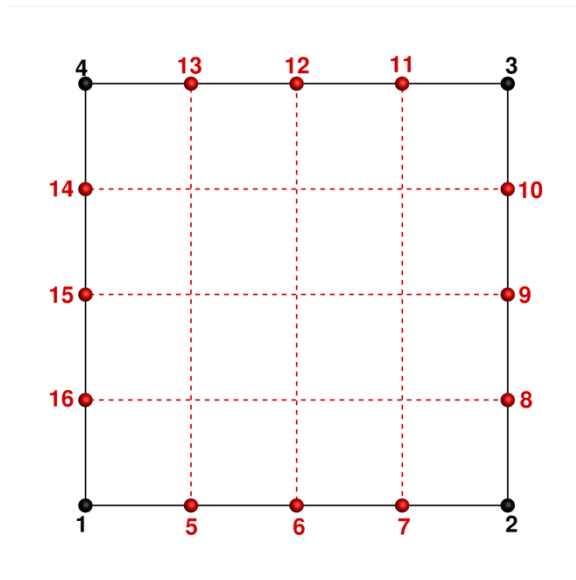
Edge Definition

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

2.2 Quadrilateral Element



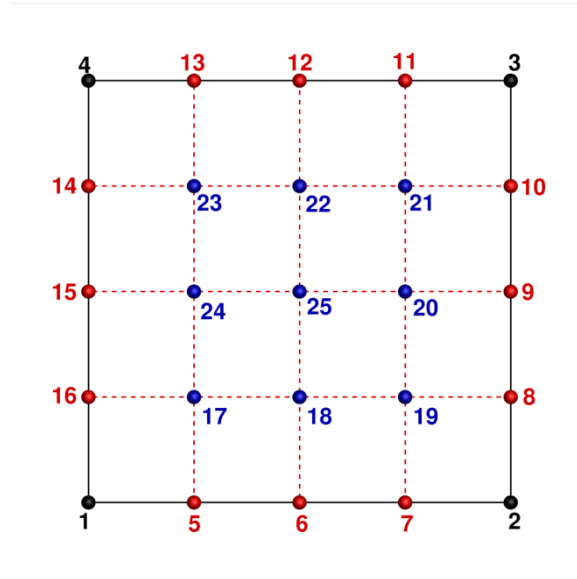
QUAD_P4_16

Edge Definition

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

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Oriented edges
F1	N1,N2,N3,N4	N5,N6,N7,N8,N9, N10,N11,N12,N13, N14,N15,N16	E1,E2,E3,E4



QUAD_25

Edge Definition

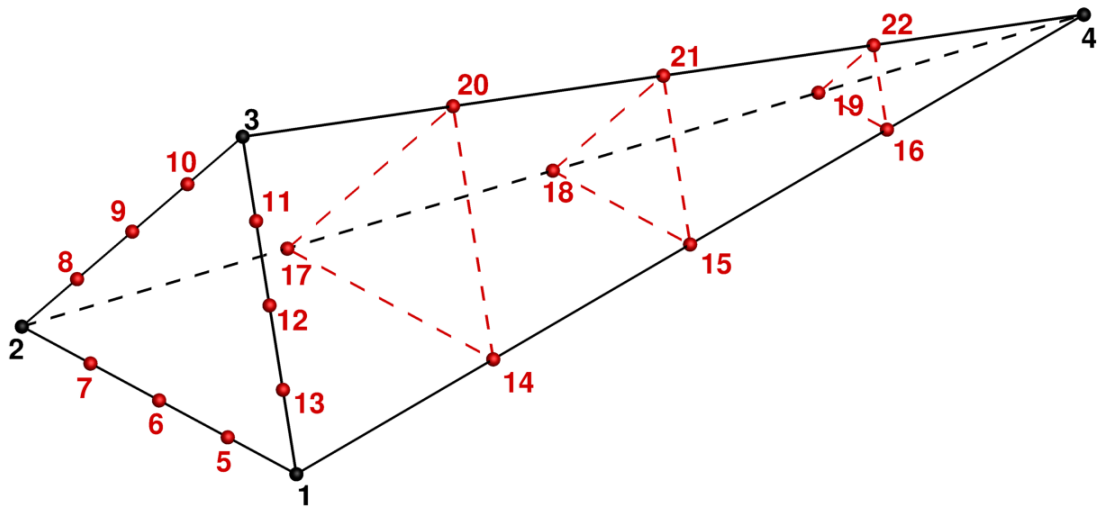
Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N5,N6,N7
E2	N2,N3	N8,N9,N10
E3	N3,N4	N11,N12,N13
E4	N4,N1	N14,N15,N16

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	N17,N18,N19, N20,N21,N22, N23,N24,N25	E1,E2,E3

3. 3-D (Volume) Element

3.1 Tetrahedral Element



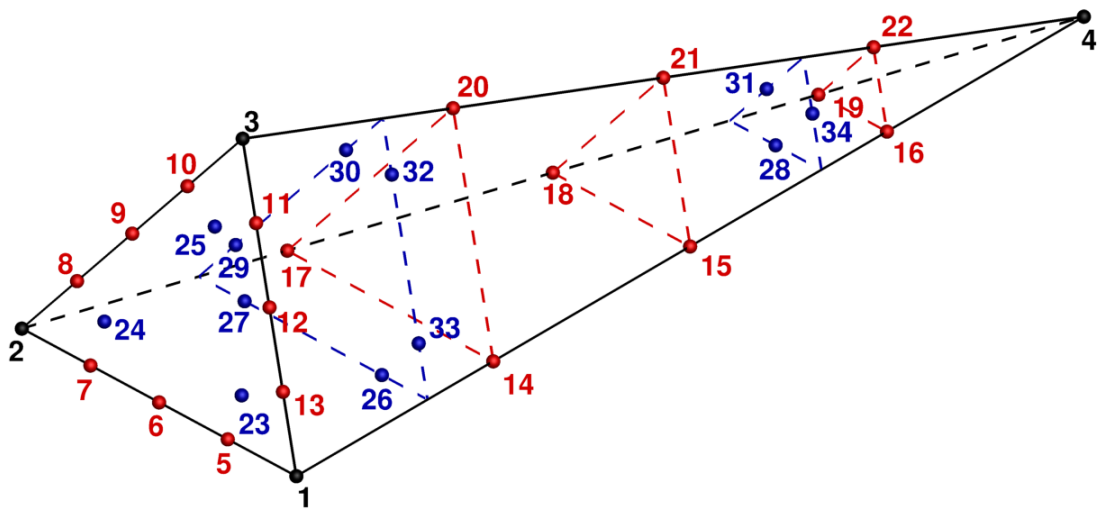
TETRA_22

Edge Definition

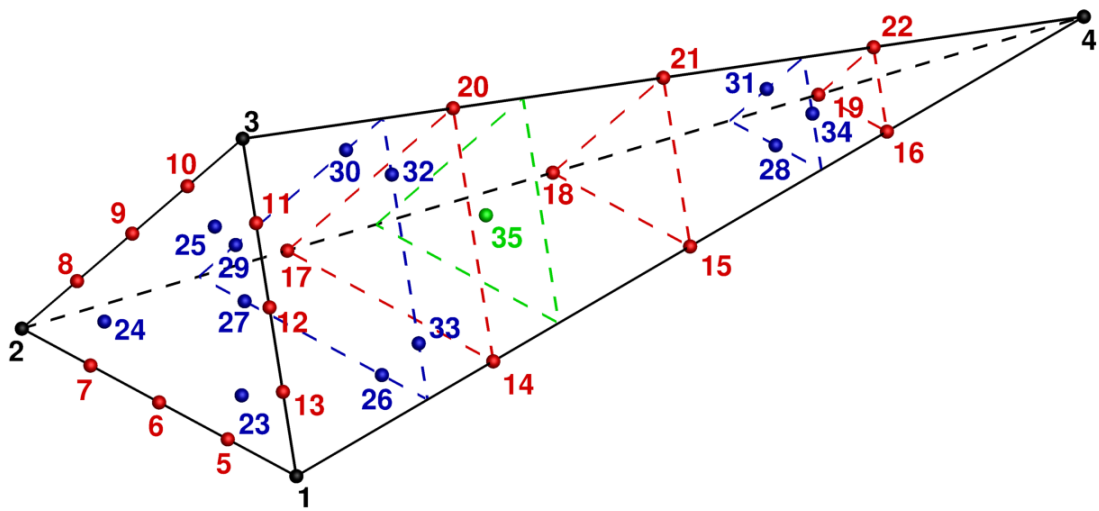
Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N5,N6,N7
E2	N2,N3	N8,N9,N10
E3	N3,N1	N11,N12,N13
E4	N1,N4	N14,N15,N16
E5	N2,N4	N17,N18,N19
E6	N3,N4	N20,N21,N22

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Oriented edges
F1	N1,N3,N2	N13,N12,N11,N10,N9,N8,N7,N6,N5	-E3,-E2,-E1
F2	N1,N2,N4	N5,N6,N7,N17,N18,N19,N16,N15,N14	E1,E5,-E4
F3	N2,N3,N4	N8,N9,N10,N20,N21,N22,N19,N18,N17	E2,E6,-E5
F4	N3,N1,N4	N11,N12,N13,N14,N15,N16,N22,N21,N20	E3,E4,-E6



TETRA_34



TETRA_35

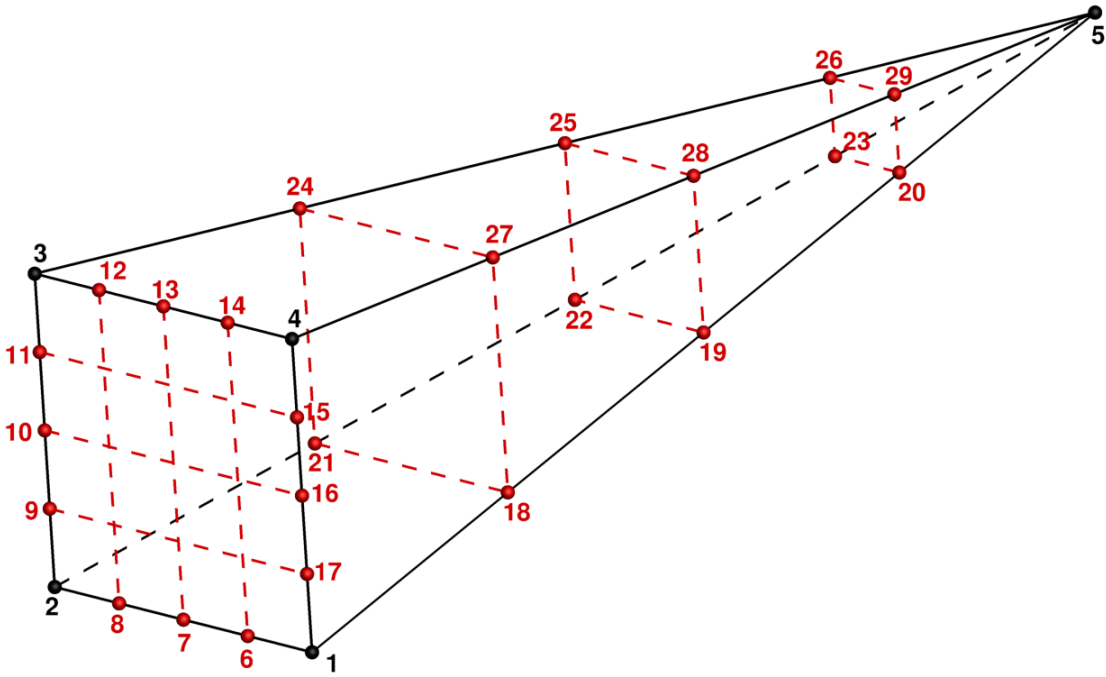
Edge Definition

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

Face Definition

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

3.2 Pyramid Element



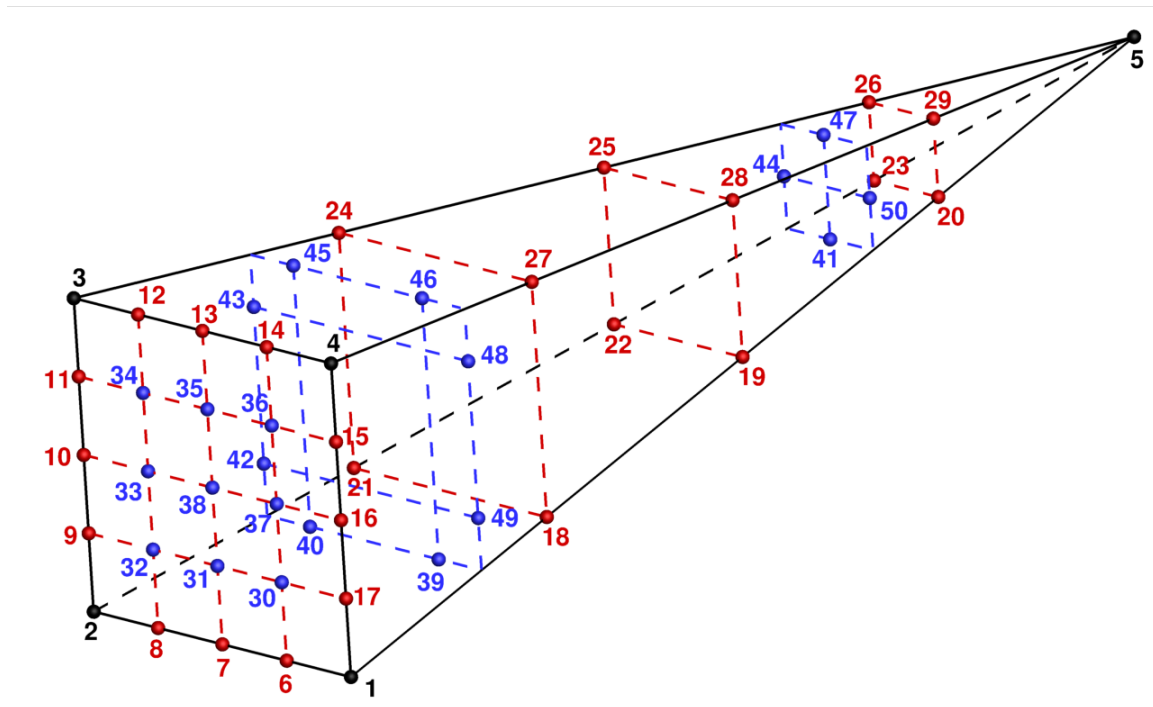
PYRA_P4_29

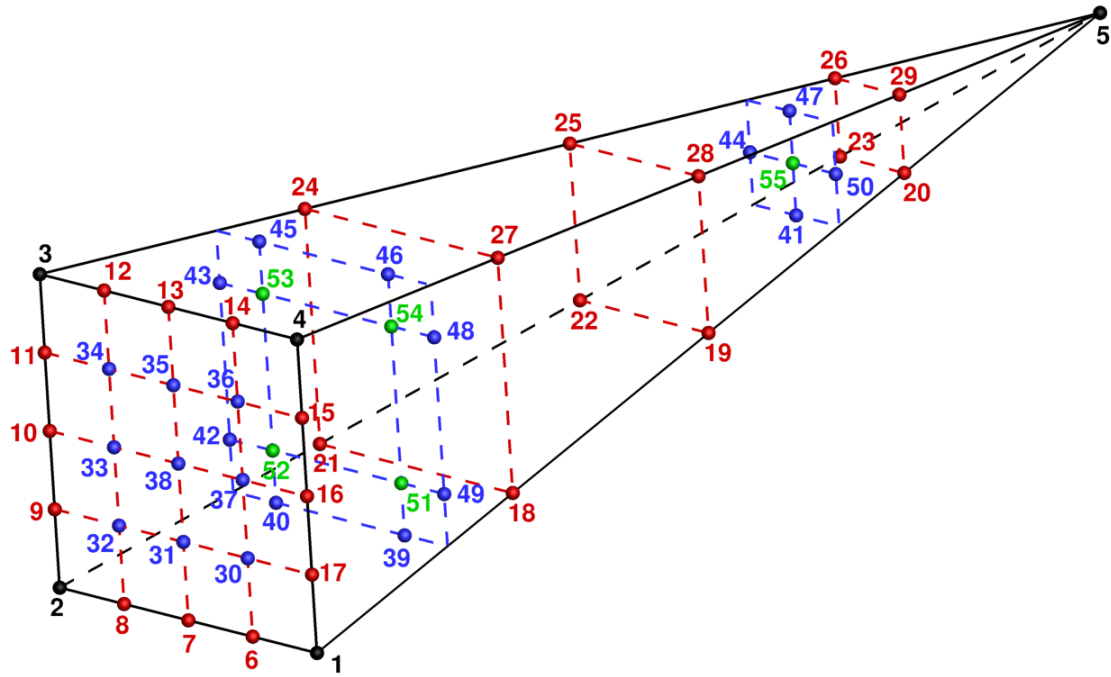
Edge Definition

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

Face Definition

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





PYRA_55

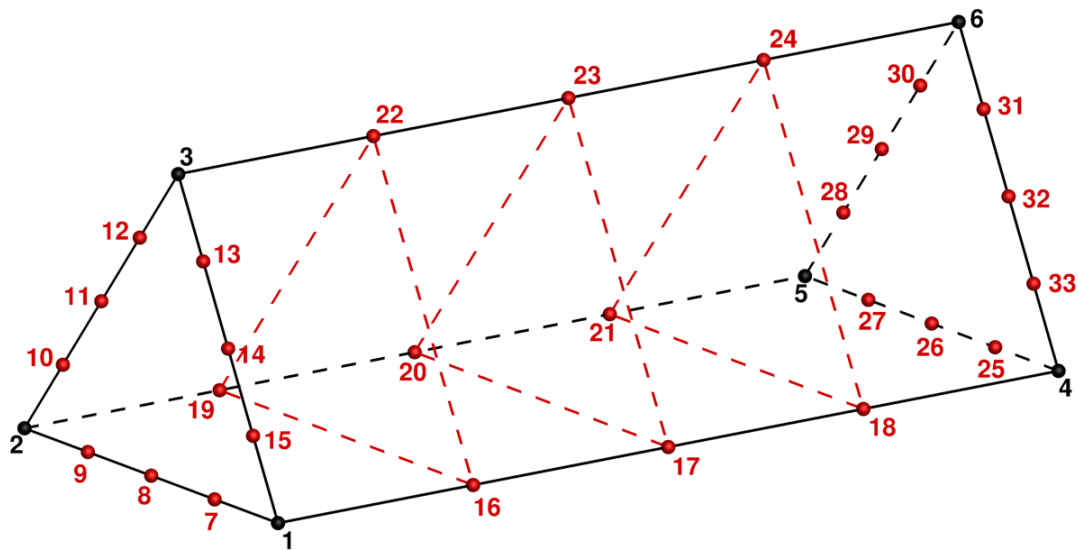
Edge Definition

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

Face Definition

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

3.3 Pentahedral Element



PENTA_33

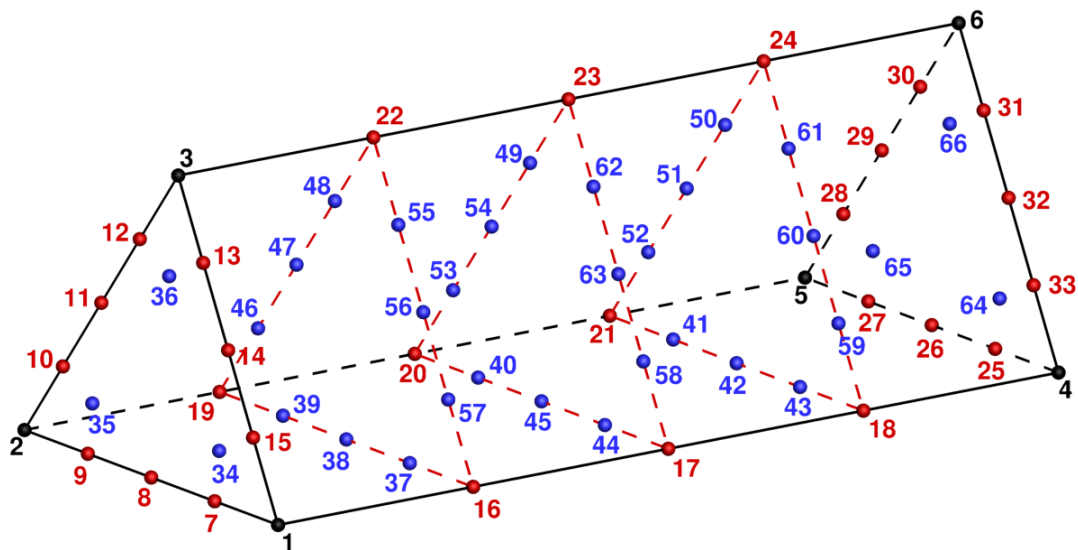
Edge Definition

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

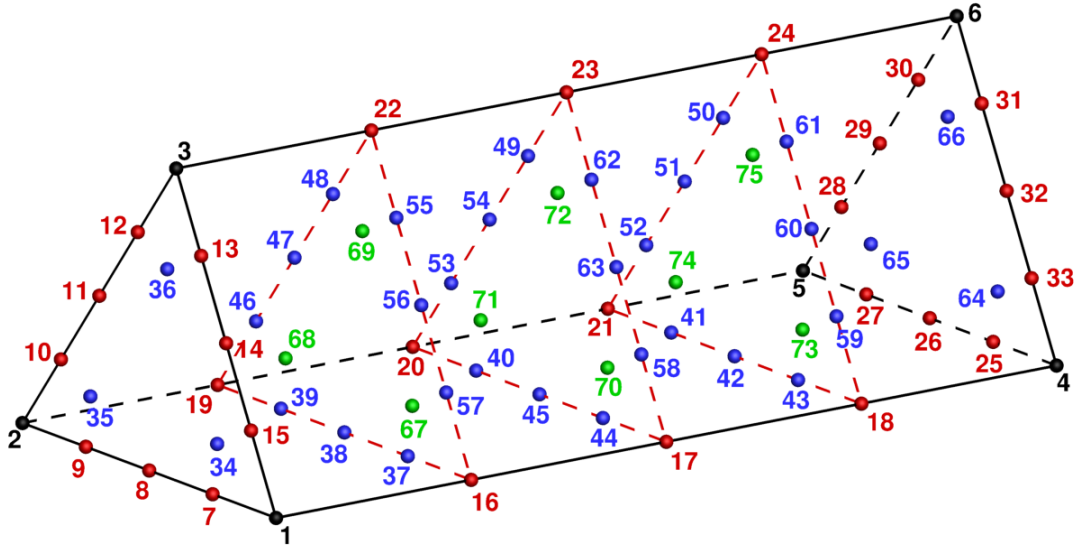
Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Oriented edges
F1	N1,N2,N5,N4	N7,N8,N9,N19,N20,N21, N27,N26,N25,N18,N17,N16	E1,E5,-E7,-E4
F2	N2,N3,N6,N5	N10,N11,N12,N22,N23,N24, N30,N29,N28,N21,N20,N19	E2,E6,-E8,-E5

F3	N3,N1,N4,N6	N13,N14,N15,N16,N17,N18, N33,N32,N31,N24,N23,N22	E3,E4,-E9,-E6
F4	N1,N3,N2	N15,N14,N13,N12,N11,N10, N9,N8,N7	-E3,-E2,-E1
F5	N4,N5,N6	N25,N26,N27,N28,N29,N30, N31,N32,N33	E7,E8,E9



PENTA_66



PENTA_75

Edge Definition

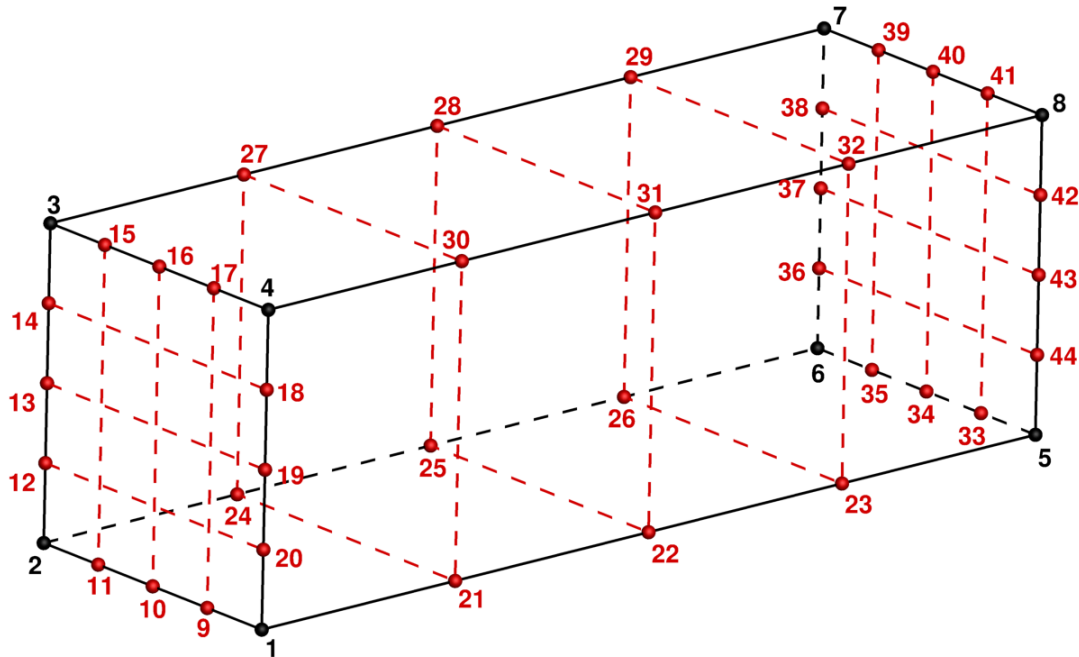
Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N7,N8,N9
E2	N2,N3	N10,N11,N12
E3	N3,N1	N13,N14,N15
E4	N1,N4	N16,N17,N18
E5	N2,N5	N19,N20,N21
E6	N3,N6	N22,N23,N24
E7	N4,N5	N25,N26,N27
E8	N5,N6	N28,N29,N30
E9	N6,N4	N31,N32,N33

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N2,N5,N4	N7,N8,N9,N19,N20,N21, N27,N26,N25,N18,N17,N16	N37,N38,N39, N40,N41,N42, N43,N44,N45	E1,E5,-E7,-E4
F2	N2,N3,N6,N5	N10,N11,N12,N22,N23,N24, N30,N29,N28,N21,N20,N19	N46,N47,N48, N49,N50,N51, N52,N53,N54	E2,E6,-E8,-E5
F3	N3,N1,N4,N6	N13,N14,N15,N16,N17,N18, N33,N32,N31,N24,N23,N22	N55,N56,N57, N58,N59,N60,	E3,E4,-E9,-E6

			N61,N62,N63	
F4	N1,N3,N2	N15,N14,N13,N12,N11,N10, N9,N8,N7	N34,N35,N36	-E3,-E2,-E1
F5	N4,N5,N6	N25,N26,N27,N28,N29,N30, N31,N32,N33	N64,N65,N66	E7,E8,E9

3.4 Hexahedral Element



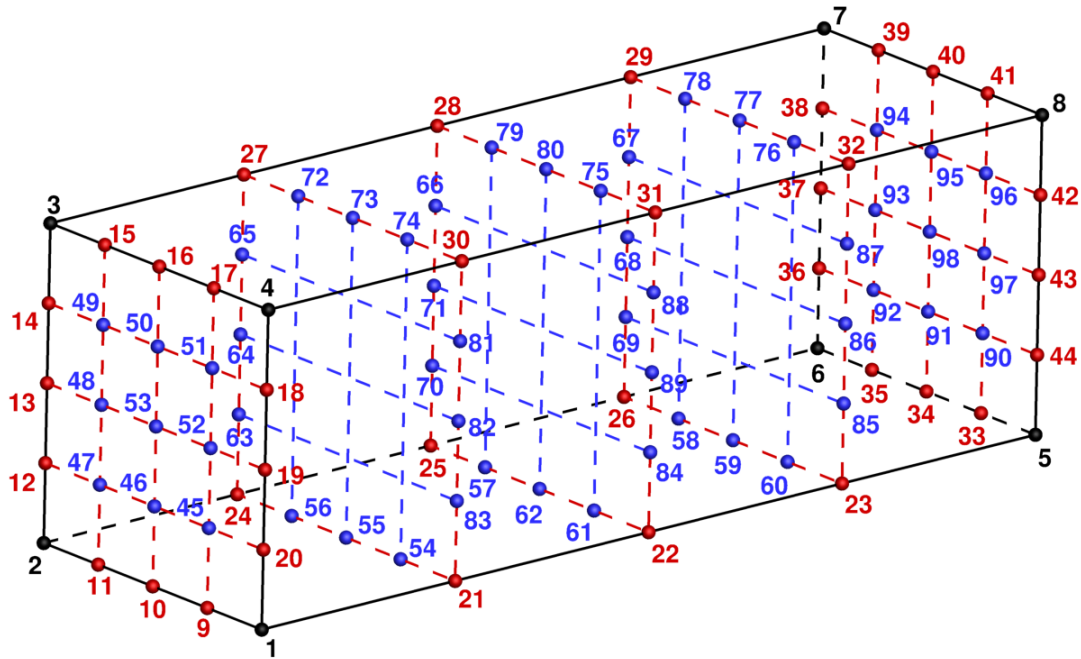
HEXA_44

Edge Definition

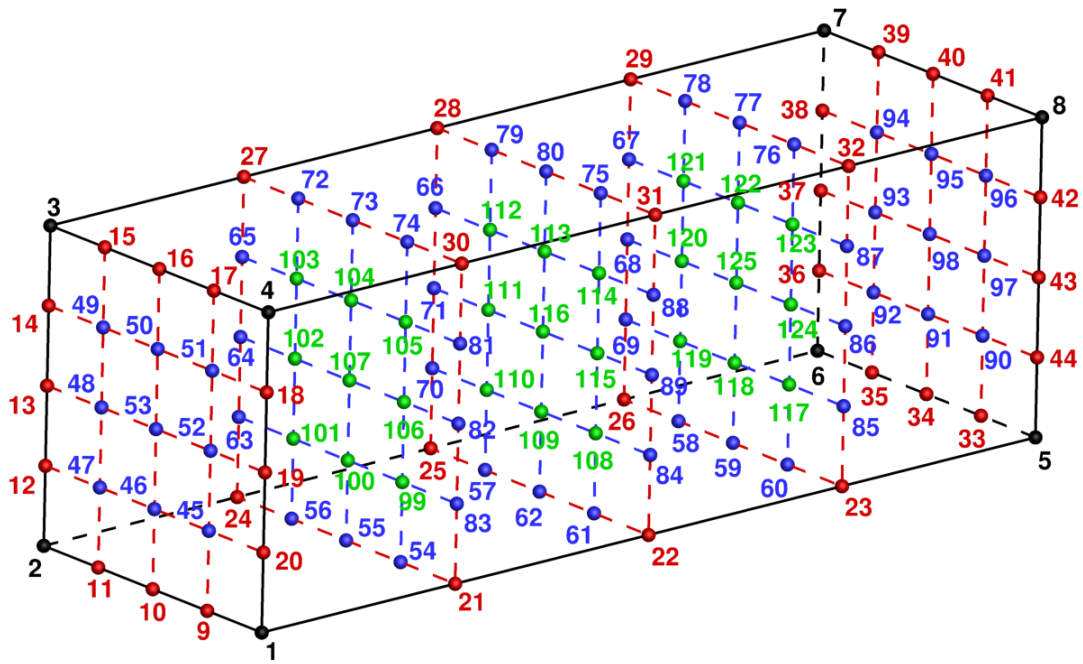
Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N9,N10,N11
E2	N2,N3	N12,N13,N14
E3	N3,N4	N15,N16,N17
E4	N4,N1	N18,N19,N20
E5	N1,N5	N21,N22,N23
E6	N2,N6	N24,N25,N26
E7	N3,N7	N27,N28,N29
E8	N4,N8	N30,N31,N32
E9	N5,N6	N33,N34,N35
E10	N6,N7	N36,N37,N38
E11	N7,N8	N39,N40,N41
E12	N8,N5	N42,N43,N44

Face Definition

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



HEXA_98



HEXA_125

Edge Definition

Oriented edges	Corner nodes	Mid-nodes
E1	N1,N2	N9,N10,N11
E2	N2,N3	N12,N13,N14
E3	N3,N4	N15,N16,N17
E4	N4,N1	N18,N19,N20
E5	N1,N5	N21,N22,N23
E6	N2,N6	N24,N25,N26
E7	N3,N7	N27,N28,N29
E8	N4,N8	N30,N31,N32
E9	N5,N6	N33,N34,N35
E10	N6,N7	N36,N37,N38
E11	N7,N8	N39,N40,N41
E12	N8,N5	N42,N43,N44

Face Definition

Oriented edges	Corner nodes	Mid-edge nodes	Mid-face nodes	Oriented edges
F1	N1,N4,N3,N2	N20,N19,N18,N17,N16,N15, N14,N13,N12,N11,N10,N9	N45,N46,N47, N48,N49,N50, N51,N52,N53	-E4,-E3,-E2,-E1
F2	N1,N2,N6,N5	N9,N10,N11,N24,N25,N26, N35,N34,N33,N23,N22,N21	N54,N55,N56, N57,N58,N59, N60,N61,N62	E1,E6,-E9,-E5
F3	N2,N3,N7,N6	N12,N13,N14,N27,N28,N29,	N63,N64,N65,	E2,E7,-E10,-E6

		N38,N37,N36,N26,N25,N24	N66,N67,N68, N69,N70,N71	
F4	N3,N4,N8,N7	N15,N16,N17,N30,N31,N32, N41,N40,N39,N29,N28,N27	N72,N73,N74, N75,N76,N77, N78,N79,N80	E3,E8,-E11,-E7
F5	N1,N5,N8,N4	N21,N22,N23,N44,N43,N42, N32,N31,N30,N18,N19,N20	N81,N82,N83, N84,N85,N86, N87,N88,N89	E5,-E12,-E8,E4
F6	N5,N6,N7,N8	N33,N34,N35,N36,N37,N38, N39,N40,N41,N42,N43,N44	N90,N91,N92, N93,N94,N95, N96,N97,N98	E9,E10,E11,E12