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LBMD: A Layer-based Mesh Data structure Tailored for Generic API Infrastructures

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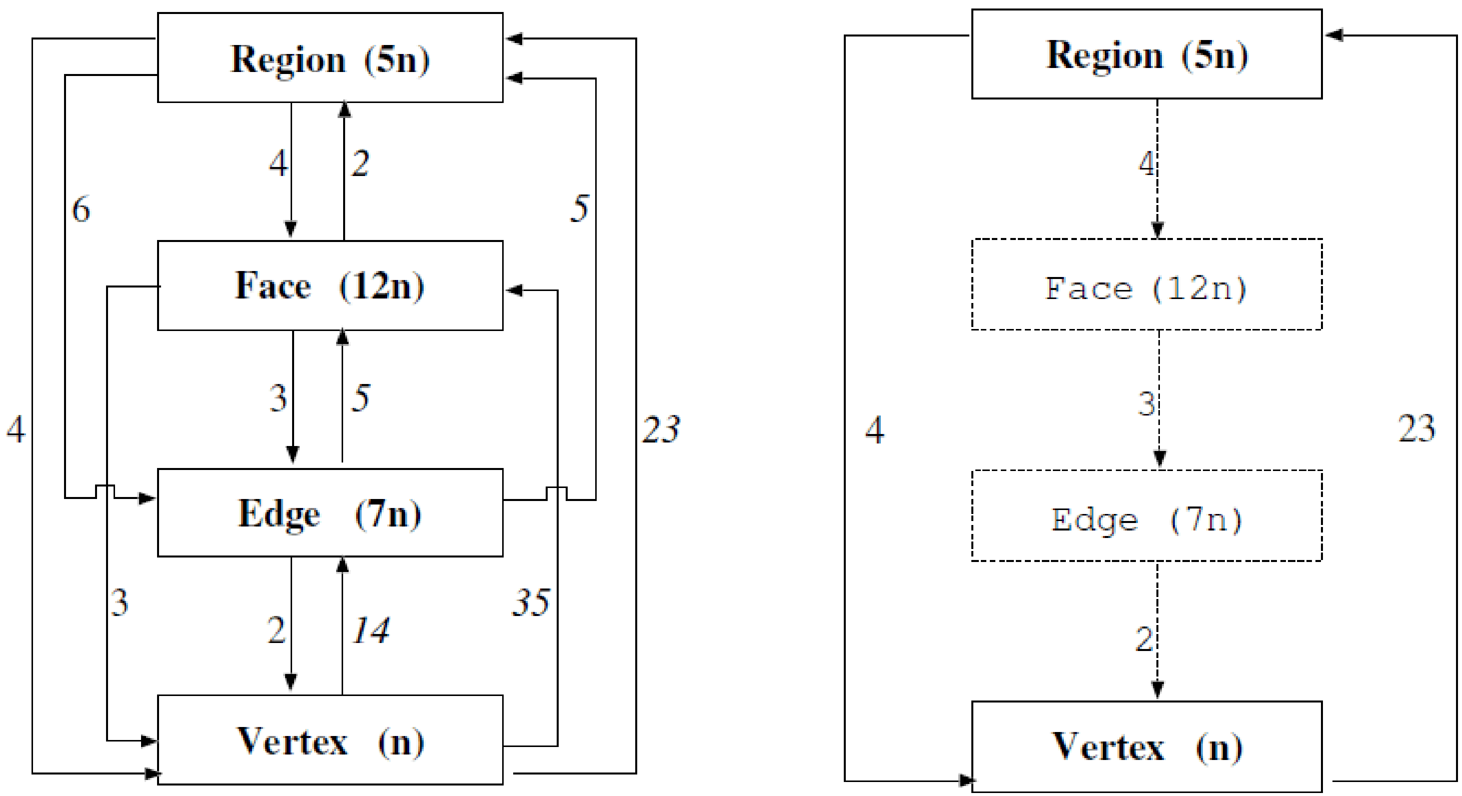
Desired Features of a Mesh Representation

- Memory requirement should be minimum
- Fast query operations
- Efficient handling of Remeshing operations.
- Utilize Structured regions if any (Query + Memory)
- Generic APIs require unique handle for each mesh entity
- Capability to iterate over all the entities at a given dimension
- Geometric operators for some solvers (MG – CV)

Different Types of Mesh Representation*



Full

Reduced

*Source : R. V. Garimella, "Mesh Data Structure Selection for Mesh Generation and FEA Applications", *International Journal of Numerical Methods in Engineering*, vol. 55, no. 4, pp. 451-478, Oct 2002

Desired Features of a Mesh Representation Full mesh representations

- Memory requirement should be minimum
- Fast query operations
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- Generic APIs require unique handle for each mesh entity
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Desired Features of a Mesh Representation
Reduced mesh representations

- Memory requirement should be minimum
- Fast query operations
- Efficient handling of Remeshing operations
- Utilize Structured regions if any (Query + Memory)
- Generic APIs require unique handle for each mesh entity
- Capability to iterate over all the entities at a given dimension
- Geometric operators for some solvers (MG – CV)

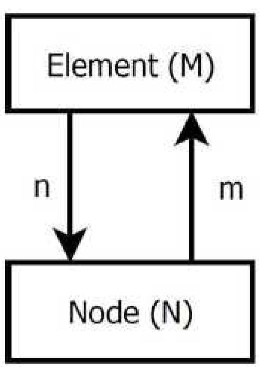
Strategy in LBMD:

- A reduced representation with minimum memory requirement.
- Fast query operations using element templates and binary search.
- Efficient handling of Remeshing operations.
- Utilize Structured regions if any (Query + Memory)
- A unique implicit handle for each mesh entity
- Capability to iterate over all the entities at a given dimension
- Geometric operators for some solvers (MG – CV)

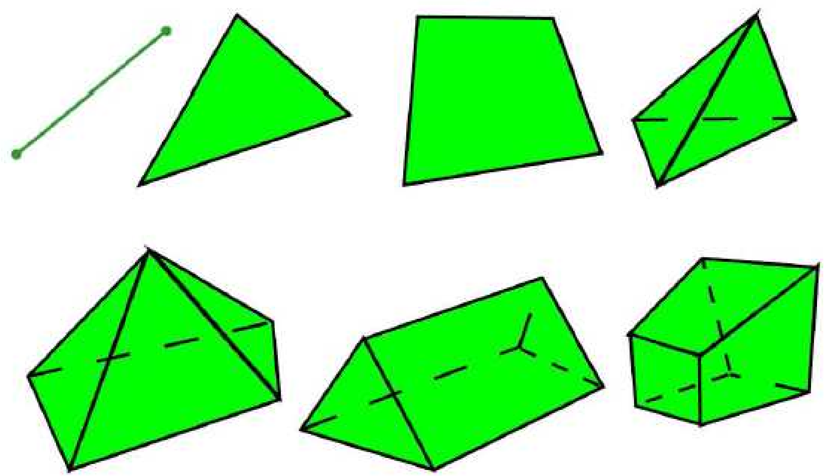
Storage in LBMD:

- LBMD Stores the non-zero entries of the connectivity matrix

$$\mathcal{C} = [c_{ij}] = \begin{cases} 1 & : \text{Node j is a corner of element i} \\ 0 & : \text{Node j is not a corner of element i} \end{cases} \quad \text{where } i = 1, 2, \ldots, M \text{ and } j = 1, 2, \ldots N$$



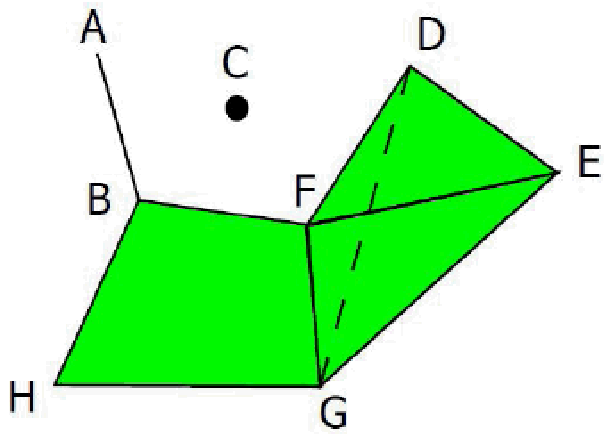
(a) Stored Connectivity



(b) Standard Elements in LBMD

Storage in LBMD:

- Blocks are utilized to improve remeshing processes



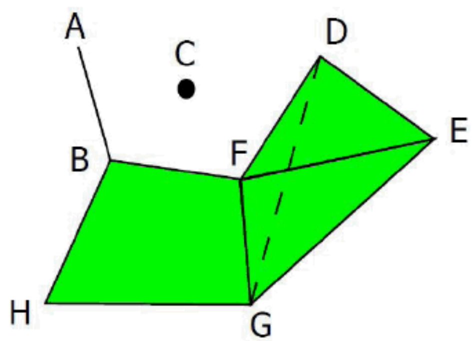
	A	B	C	D	E	F	G	H
e1	1	1	0	0	0	0	0	0
e2	0	0	0	1	1	1	1	0
e3	0	1	0	0	0	1	1	1

Element Block 0	Vertex Block 0	Vertex Coordinate Block 0
0 0 1	1 0	x_A y_A z_A
8187 3 5 4 6	2 0 2	x_B y_B z_B
58 5 1 7 6	0	x_C y_C z_C
	1 1	x_D y_D z_D
	1 1	x_E y_E z_E
	2 1 2	x_F y_F z_F
	2 1 2	x_G y_G z_G
	1 2	x_H y_H z_H

- The number of elements in a block is limited to 2^17 = 131,072

- The number of blocks are limited to 2^10 = 1024

Implicit Handle:



	A	B	C	D	E	F	G	H
e1	1	1	0	0	0	0	0	0
e2	0	0	0	1	1	1	1	0
e3	0	1	0	0	0	1	1	1

Block index (10)	Local index (17)	Flag (5)

- A 32 bit size_t handle is assumed here

$\mathcal{F}$	Description of the mesh topology associated with that handle
1	A vertex
2	An element
3-8	A face in a volumetric element, the local index of that face in its parent element is given by $\mathcal{F} - 3$
9-20	An edge in a surface or volumetric element, the local index of that edge in its parent element is given by $\mathcal{F} - 9$

Implicit Handles
A:1, B:33, C:65, D:97, E:129, F:161, G:193, H:225
AB:2, DF:41, FE:42, ED:43, DG:44, FG:45, EG:46, FB:73, BH:74, HG:75
DFE:35, DGF: 36, FGE:37, EGD:38, FBHG: 66
DFEG:34

- A parent element is the first created one
- Total number of elements = 2^27 = 134,217,728

38 = 0 * 2^22 + 1 * 2^5 + 6 → fourth face in element 1 in block 0

8187 = 1023 * 2^3 + 3→ A tetrahedron (parent of its four faces and six edges)

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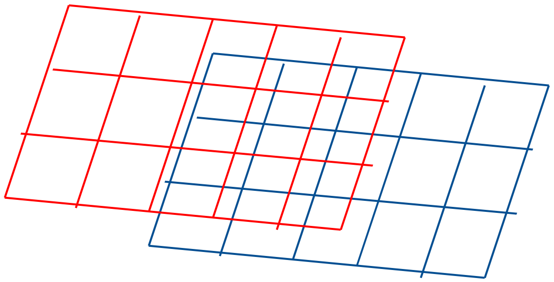
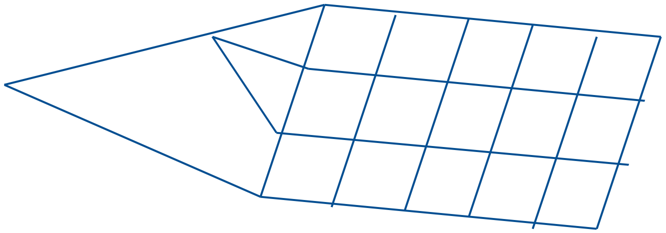
Handling of structured regions in a hybrid mesh:

- A given element Block is reserved for those (Block A) based on the first structured region to be introduced.
- Each row in that block stores a structured region using number of rows in each direction.
- This info is sufficient to get the element-nodes and the node-elements relations via integer operations.
- Mapping information is stored to connect a boundary node to its virtual unstructured or structured one.





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Concept of Layers

- Each block could be assigned to a given layer using a single variable. This allows us to:
  1. Store different levels of MG using the same point cloud.
  2. Load two different objects into the same model with the capability of iterating over the entities of each model separately (Easy merging)
  3. Dual grids can be connected easily by storing the element surrounding a given node
  4. An advancing front algorithm could create the final elements in a layer while having the moving front in another one (removes ambiguity in query operations)

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Thank you !