Multiscale decomposition of Hex meshes from Geosciences. Study of lossless compression performance

Lauriane Bouard[1,2], Laurent Duval[1], Frédéric Payan[2], Marc Antonini[2]

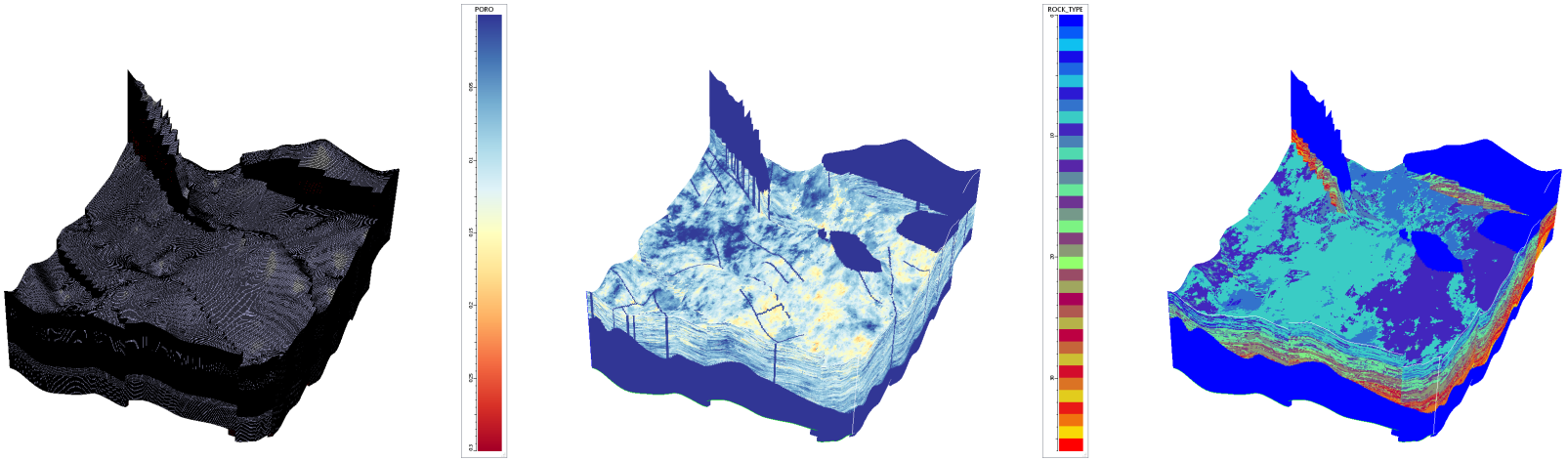
[1]IFP Energies nouvelles, France

[2]Université Côte d'Azur, CNRS, I3S, France

COmpression et REpresentation des Signaux Audiovisuels
November 13^{th} 2018, Poitiers

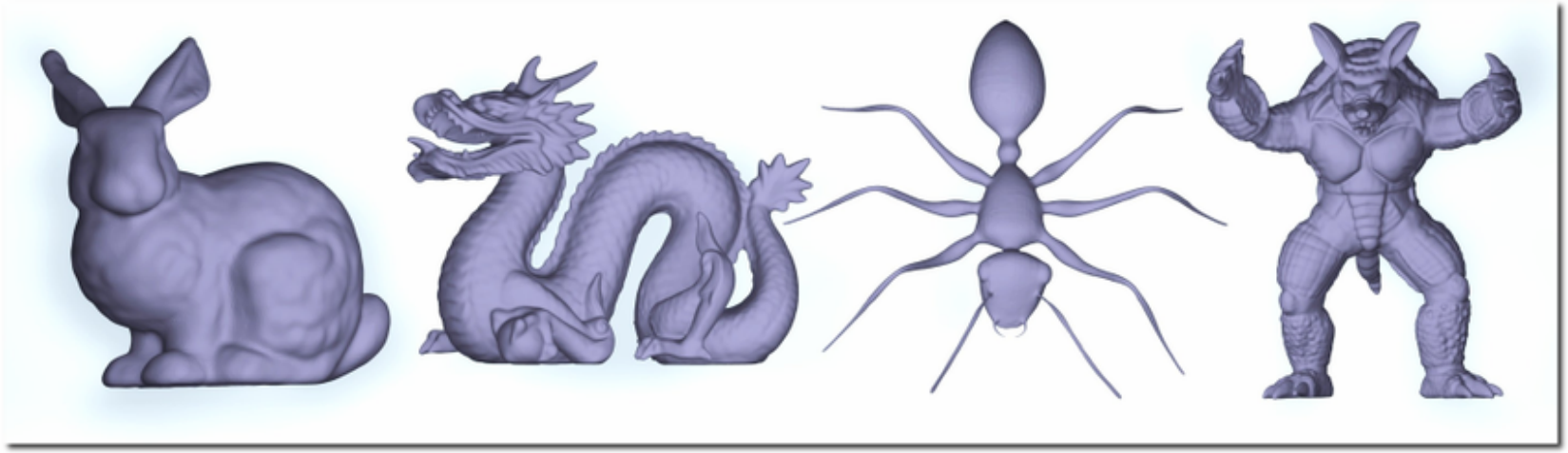
Compression challenges

- Object made of various components
  - Hex mesh with geometrical discontinuities
  - Additional properties

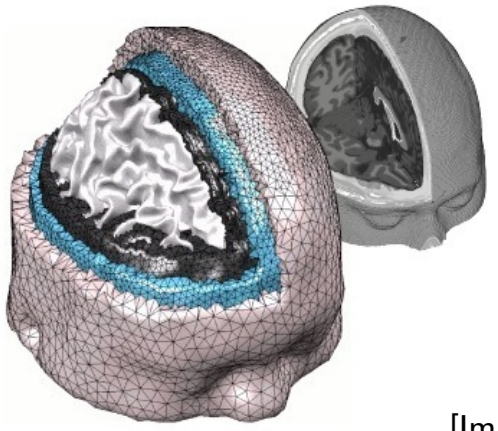


1.1 Standard meshes

Surface meshes



Volume meshes

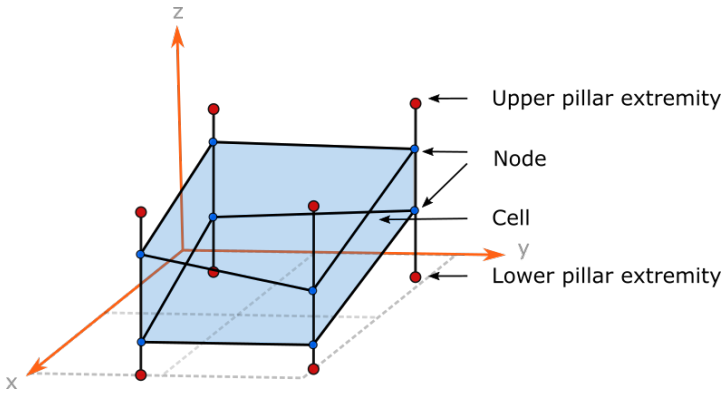


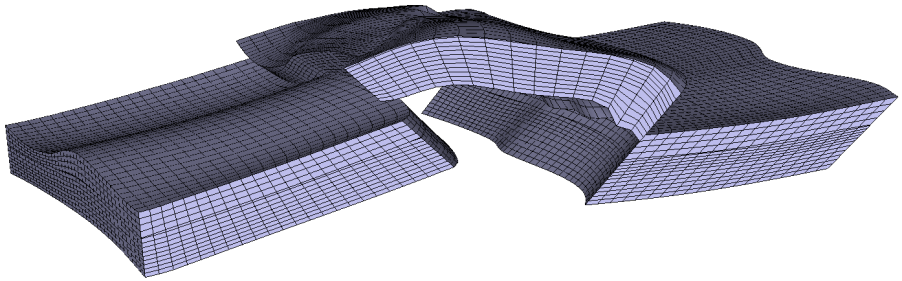
[Image from iso2mesh: mesh generator for Matlab]

1.2 Geoscience meshes

Features

- Structure
  - Corner Point Grid format (CPG)
  - Fault network
- Cell activity
- Properties:

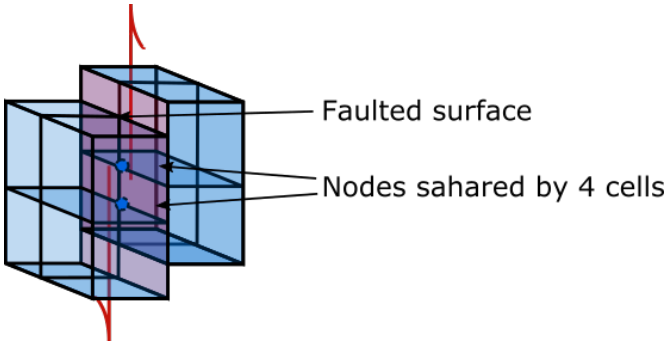


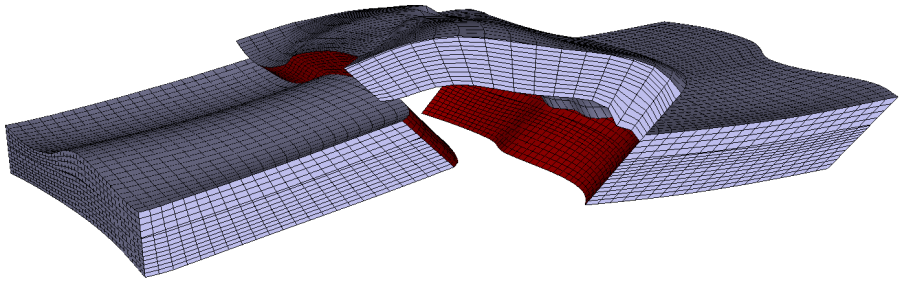


1.2 Geoscience meshes

Features

- Structure
  - Corner Point Grid format (CPG)
  - Fault network
- Cell activity
- Properties:

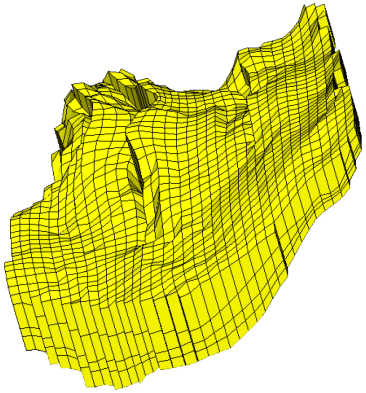


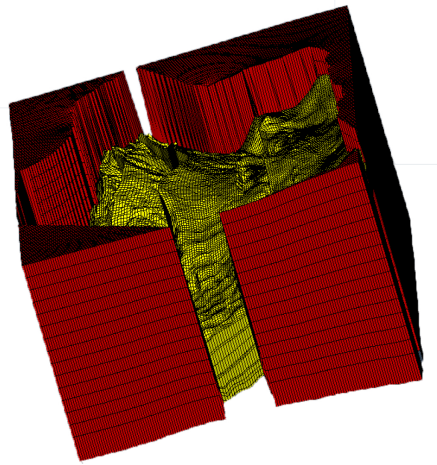


1.2 Geoscience meshes

Features

- Structure
  - Corner Point Grid format (CPG)
  - Fault network
- Cell activity
- Properties:

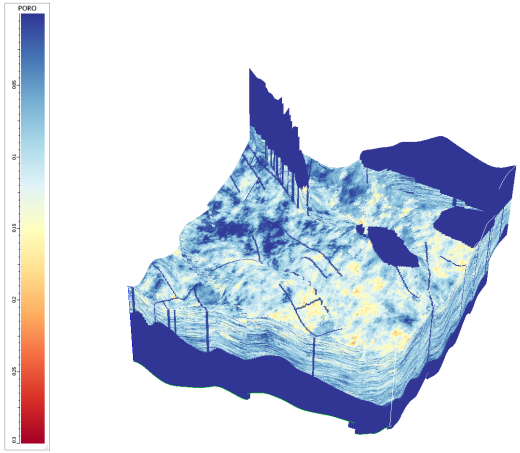




1.2 Geoscience meshes

Features

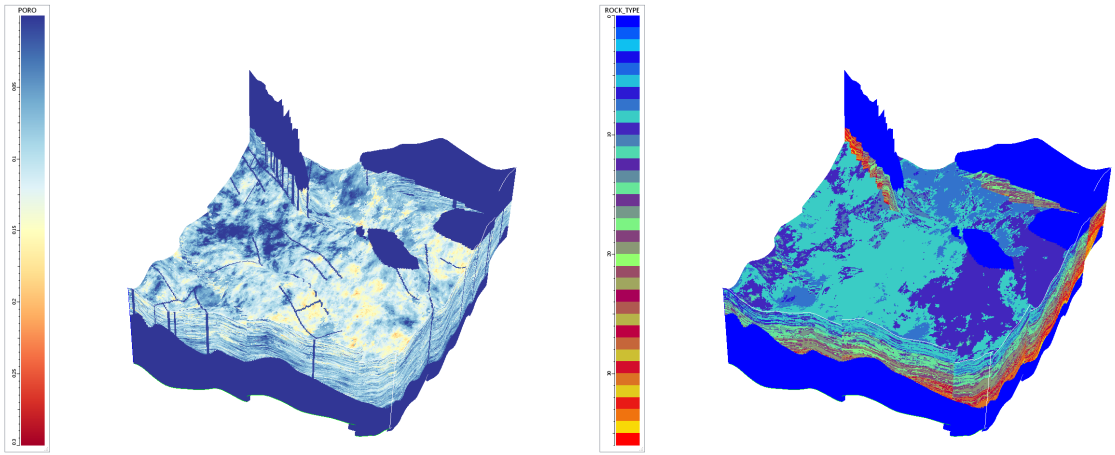
- Structure
  - Corner Point Grid format (CPG)
  - Fault network
- Cell activity
- Properties: continuous ($\mathbb{R}$) (with high dynamic)



1.2 Geoscience meshes

Features

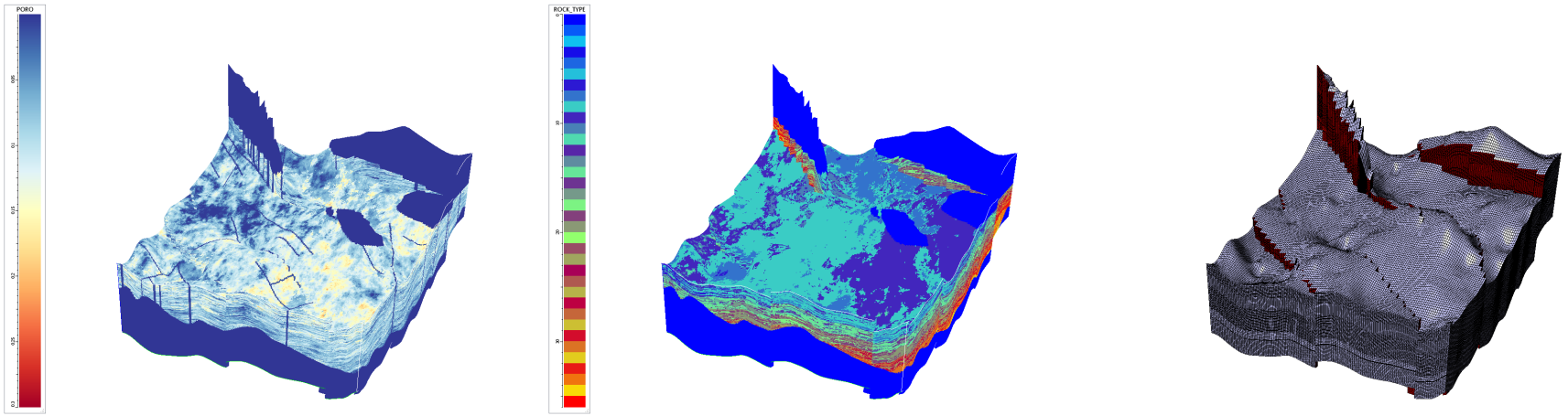
- Structure
  - Corner Point Grid format (CPG)
  - Fault network
- Cell activity
- Properties: continuous ($\mathbb{R}$)/categorical ($\mathbb{N}$)



1.2 Geoscience meshes

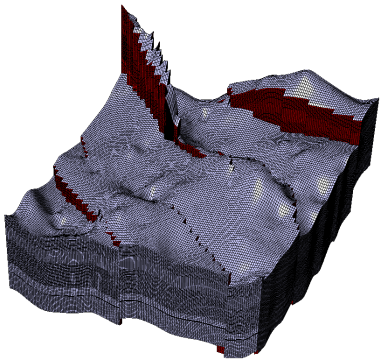
Features

- Structure
  - Corner Point Grid format (CPG)
  - Fault network
- Cell activity
- Properties: continuous ($\mathbb{R}$)/categorical ($\mathbb{N}$)



1.3 HexaShrink decomposition [PDS+16] [PDP+18]

Analysis levels

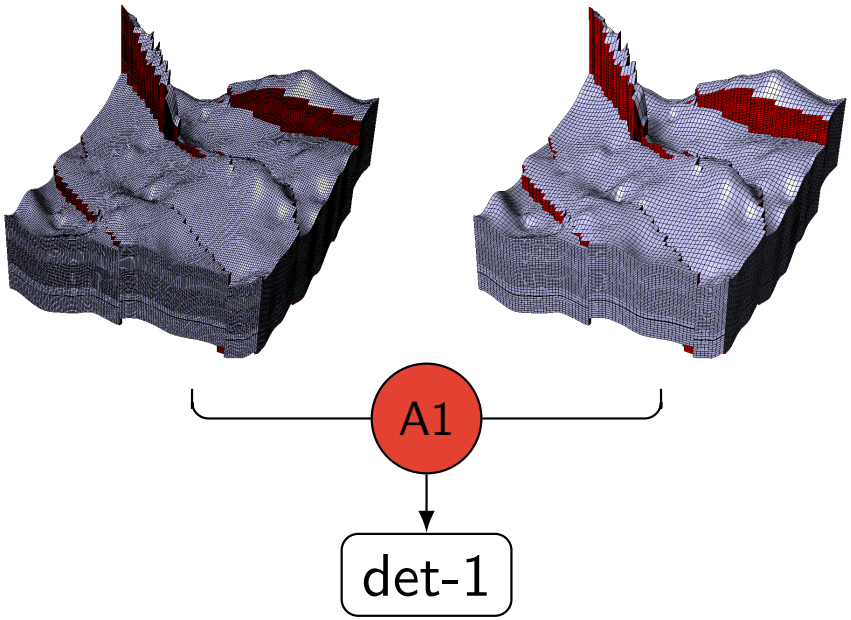


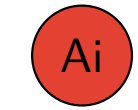
Ai — i Analysis step of wavelet decomposition

det-i — i wavelet detail

1.3 HexaShrink decomposition [PDS+16] [PDP+18]

Analysis levels



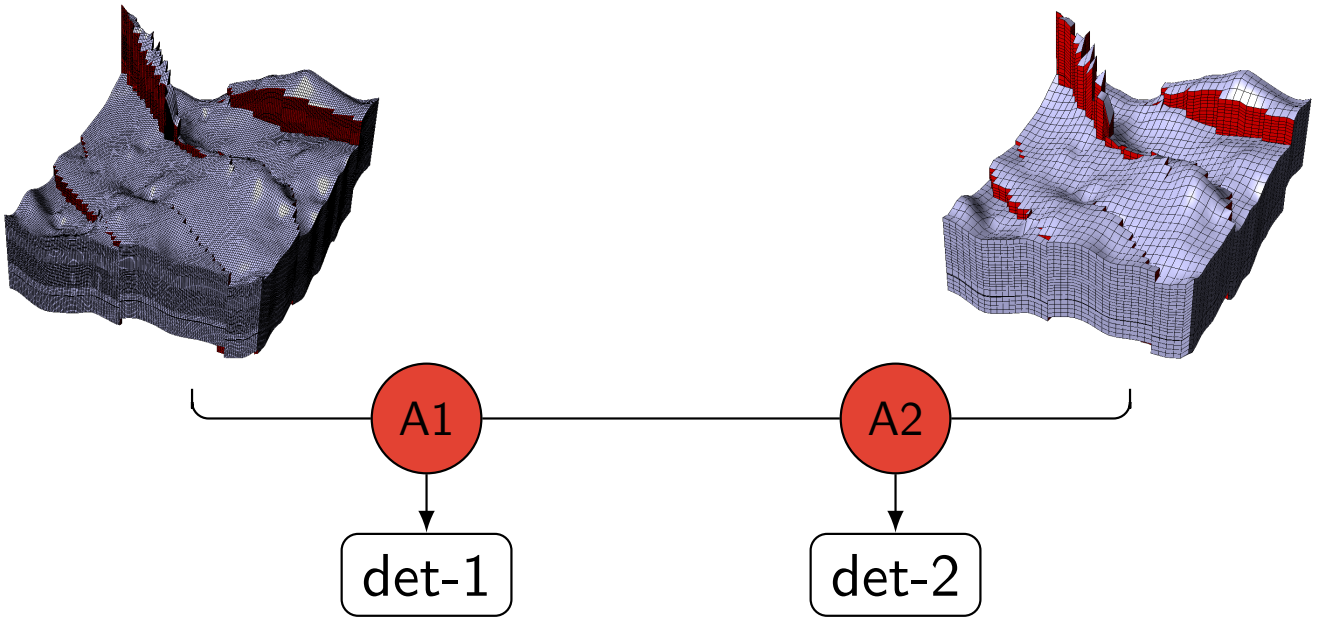


i Analysis step of wavelet decomposition

i wavelet detail

1.3 HexaShrink decomposition [PDS+16] [PDP+18]

Analysis levels

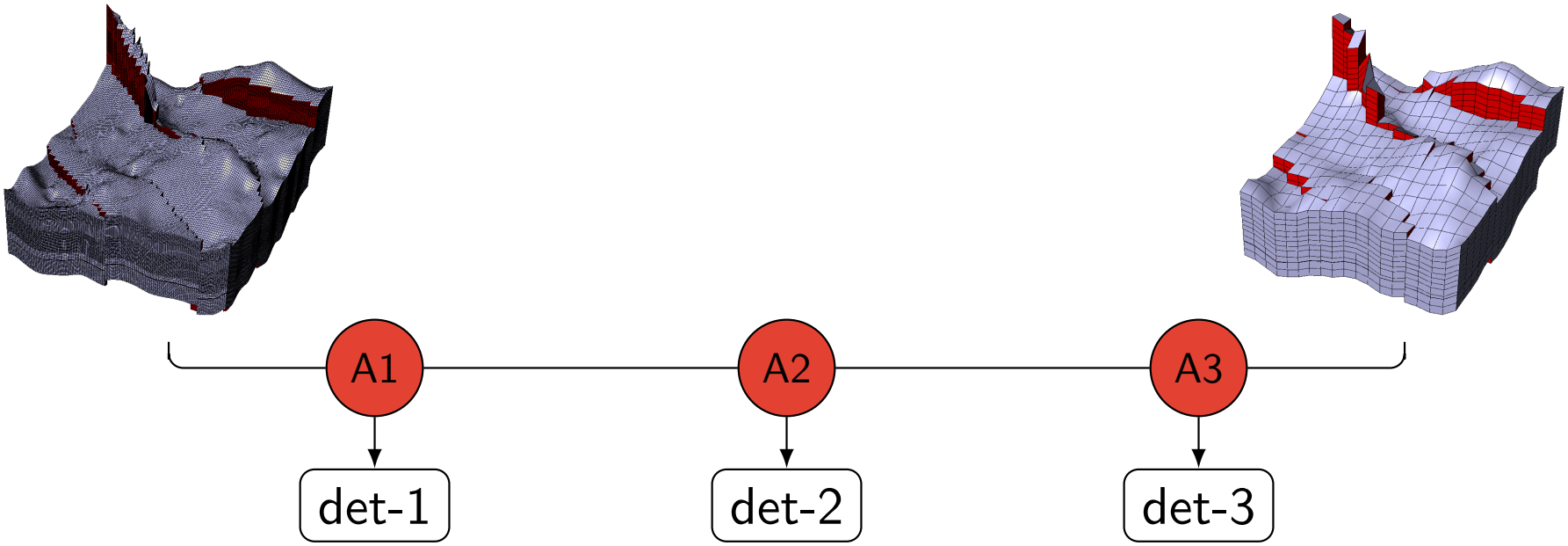


Ai — i Analysis step of wavelet decomposition

det-i — i wavelet detail

1.3 HexaShrink decomposition [PDS+16] [PDP+18]

Analysis levels



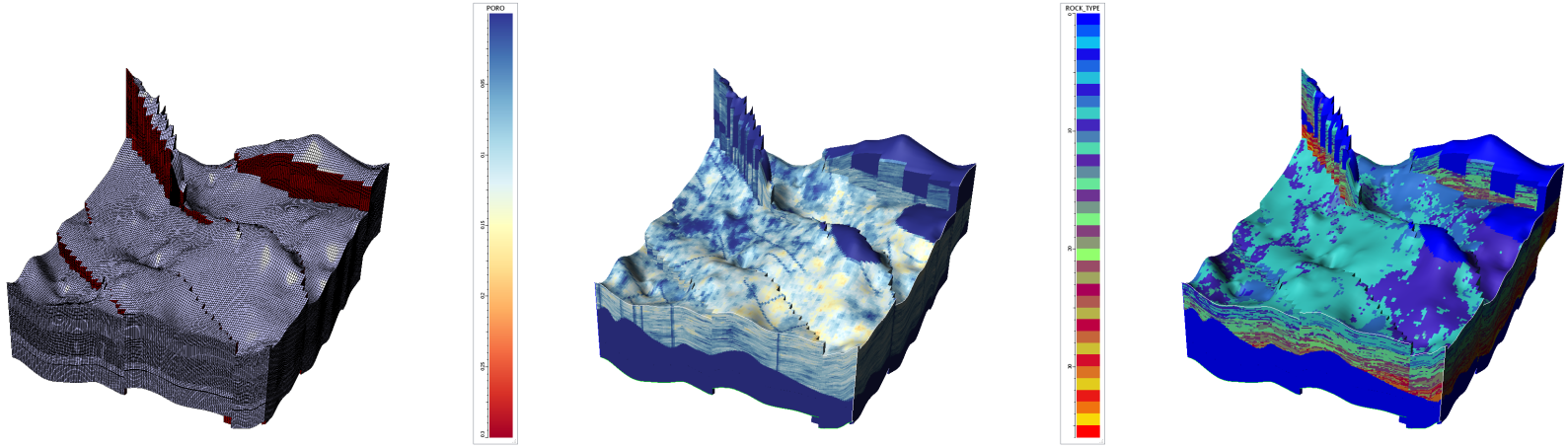
Ai — i Analysis step of wavelet decomposition

det-i — i wavelet detail

1.3 HexaShrink decomposition [PDS+16] [PDP+18]

Mesh components

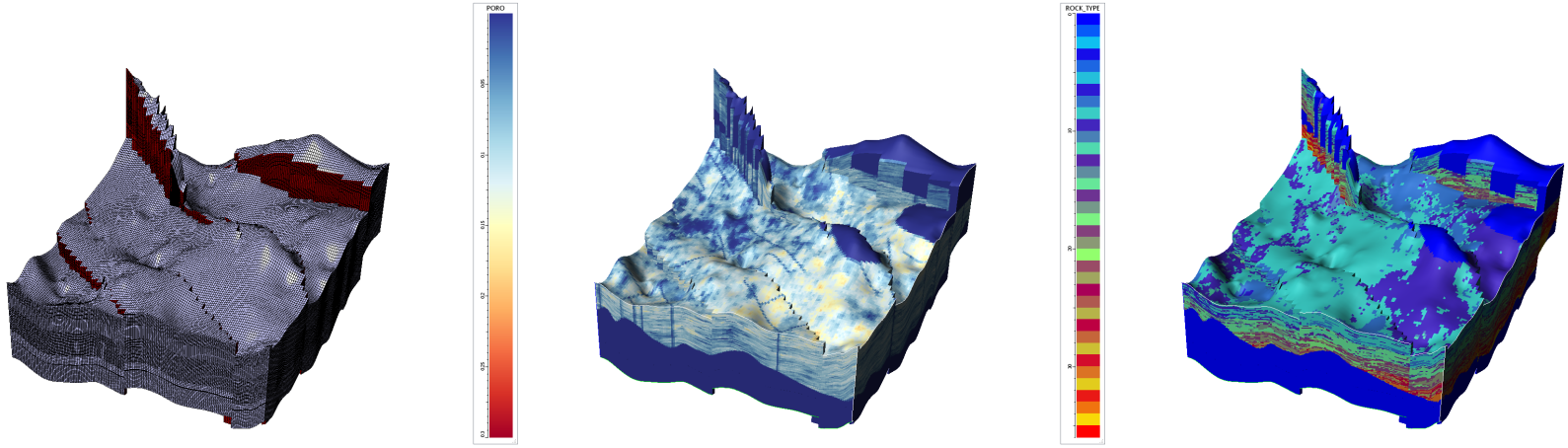
- Geometry
  - Pillar
  - Zcorn
- Cell activity
- Properties
  - Categorical
  - Continuous



1.3 HexaShrink decomposition [PDS+16] [PDP+18]

Multiscale coherency

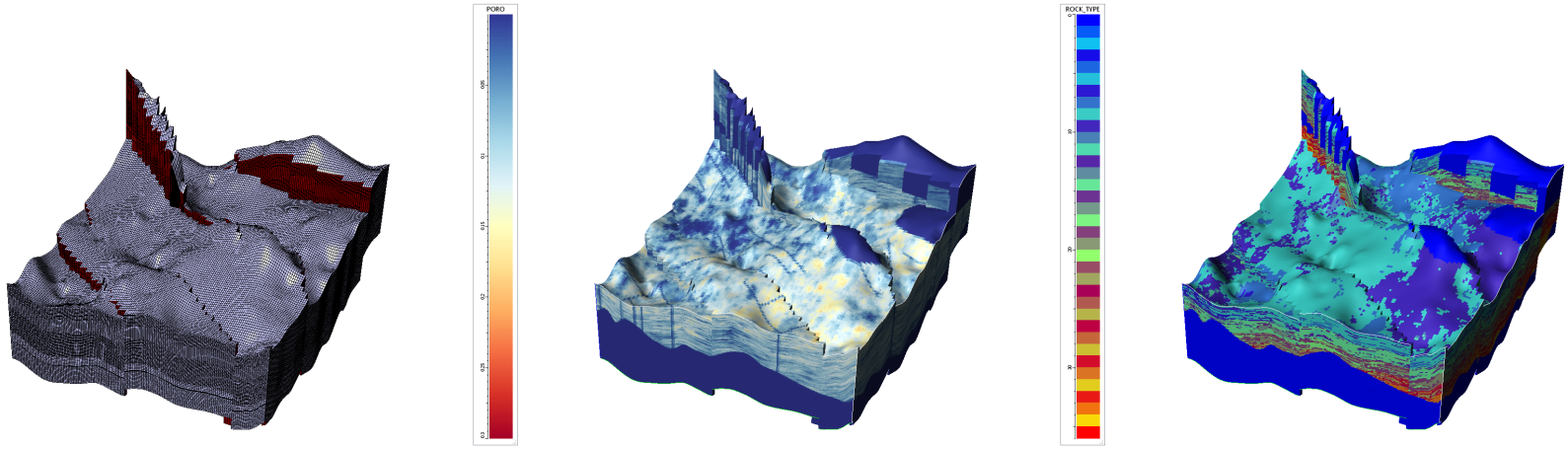
- Geometry
  - Pillar → Fault preservation
  - Zcorn → Global shape preservation
- Cell activity → Borders preservation
- Properties
  - Categorical → Properties preservation
  - Continuous → " "



1.3 HexaShrink decomposition [PDS+16] [PDP+18]

Transformation according to the components

- Geometry
  - Pillar → 2D morphological wavelet
  - Zcorn → non-linear 1D wavelet
- Cell activity → boolean 3D wavelet
- Properties
  - Categorical → modelet [patented]
  - Continuous → 3D Haar wavelet



2.1 Compression challenge

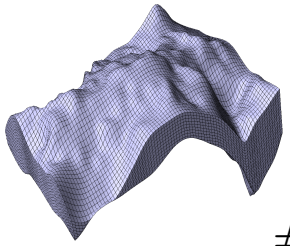
What is the best way to encode the decomposed data?

Compression settings optimization

- Various types of **meshes** (dimensions, structure and properties)
- Various wavelet **decomposition levels** performed
- Various types of **lossless coders** used

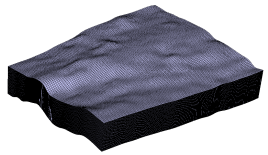
2.1 Benchmark description

Fault inclusions
Cell number
Global size



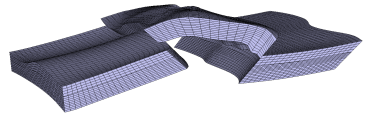
#1

faults
93 600
4.62 MB



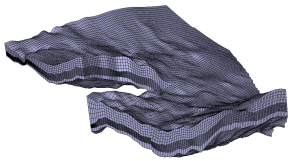
#2

faults
1 000 000
42.46 MB



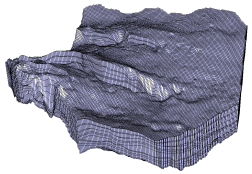
#3

faults
36 816
1.46 MB



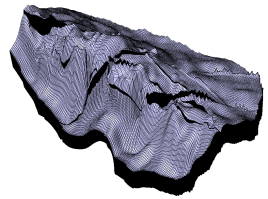
#4

faults
210 000
7.88 MB



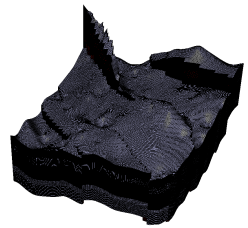
#5

faults
450 576
22.73 MB



#6

faults
6 577 325
274.57 MB



#7

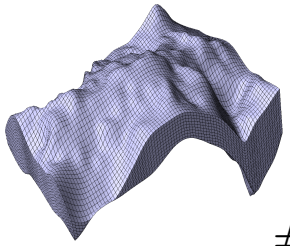
faults
13 947 600
580.94 MB

2.1 Benchmark description

Fault inclusions

Cell number

Global size

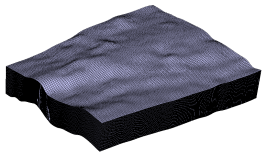


#1

~~faults~~

93 600

4.62 MB

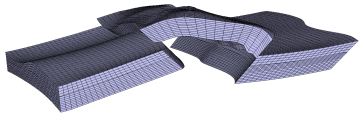


#2

~~faults~~

1 000 000

42.46 MB

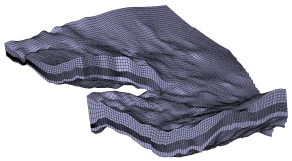


#3

faults

36 816

1.46 MB

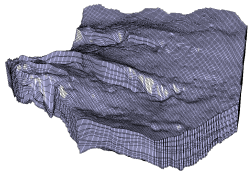


#4

faults

210 000

7.88 MB

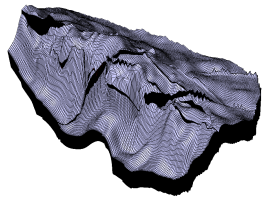


#5

faults

450 576

22.73 MB

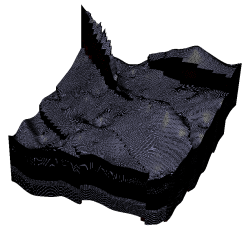


#6

faults

6 577 325

274.57 MB



#7

faults

13 947 600

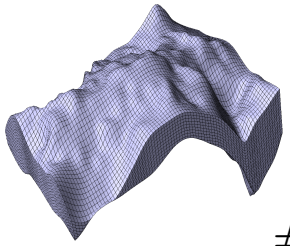
580.94 MB

2.1 Benchmark description

Fault inclusions

Cell number

Global size

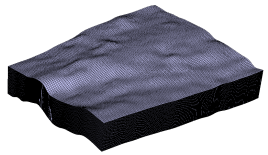


#1

faults

93 600

4.62 MB

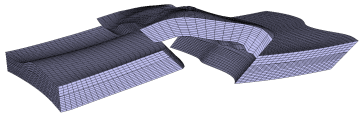


#2

faults

1 000 000

42.46 MB

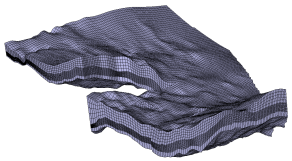


#3

faults

36 816

1.46 MB

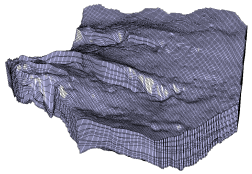


#4

faults

210 000

7.88 MB

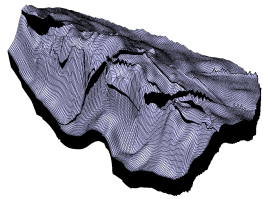


#5

faults

450 576

22.73 MB

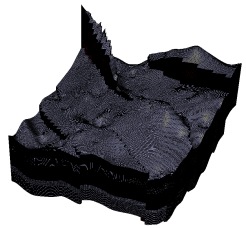


#6

faults

6 577 325

274.57 MB



#7

faults

13 947 600

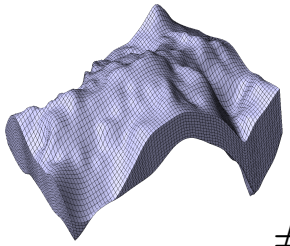
580.94 MB

2.1 Benchmark description

Fault inclusions

Cell number

Global size

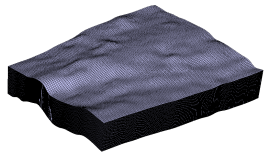


#1

faults

93 600

4.62 MB

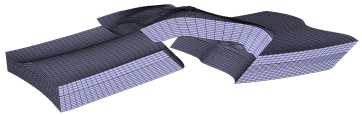


#2

faults

1 000 000

42.46 MB

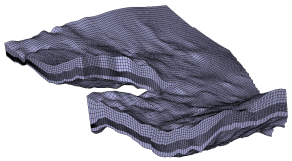


#3

faults

36 816

1.46 MB

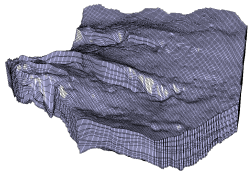


#4

faults

210 000

7.88 MB

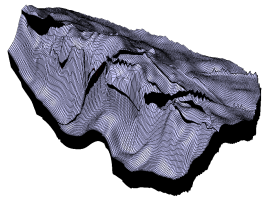


#5

faults

450 576

22.73 MB

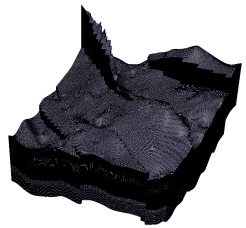


#6

faults

6 577 325

274.57 MB



#7

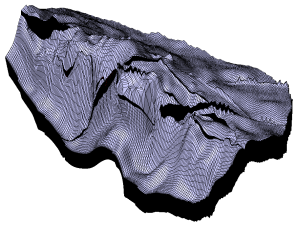
faults

13 947 600

580.94 MB

2.2 Comparative performance

On mesh#6



#6

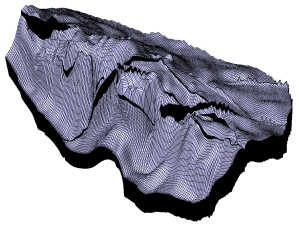
Features		Compression rate			
Faults	File Size	Level	gzip	bzip2	LZMA
Yes	274.57 MB	none	2.31	2.25	3.04
		1	3.31	3.53	4.44
		2–6	4.14–4.24	4.48–4.68	5.54–5.73

Results

- Positive performances of lossless coders
- HexaShrink improves the compression rate
- Less significant improvements above two levels

2.2 Comparative performance

On mesh#6



#6

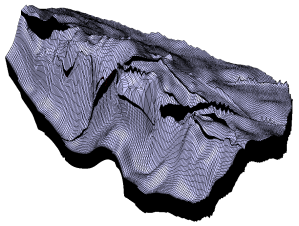
Features		Compression rate			
Faults	File Size	Level	gzip	bzip2	LZMA
Yes	274.57 MB	none	2.31	2.25	3.04
		1	3.31	3.53	4.44
		2–6	4.14–4.24	4.48–4.68	5.54–5.73

Results

- Positive performances of lossless coders
- HexaShrink improves the compression rate
- Less significant improvements above two levels

2.2 Comparative performance

On mesh#6



#6

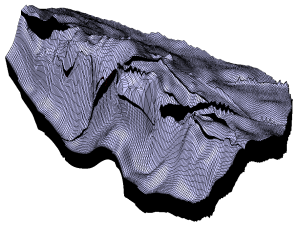
Features		Compression rate			
Faults	File Size	Level	gzip	bzip2	LZMA
Yes	274.57 MB	none	2.31	2.25	3.04
		1	3.31	3.53	4.44
		2–6	4.14–4.24	4.48–4.68	5.54–5.73

Results

- Positive performances of lossless coders
- HexaShrink improves the compression rate
- Less significant improvements above two levels

2.2 Comparative performance

On mesh#6



#6

Features		Compression rate			
Faults	File Size	Level	gzip	bzip2	LZMA
Yes	274.57 MB	none	2.31	2.25	3.04
		1	3.31	3.53	4.44
		2–6	4.14–4.24	4.48–4.68	5.54–5.73

Results

- Positive performances of lossless coders
- HexaShrink improves the compression rate
- Less significant improvements above two levels

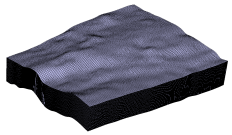
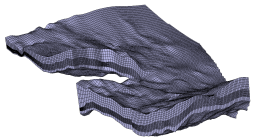
2.2 Comparative performance

All meshes

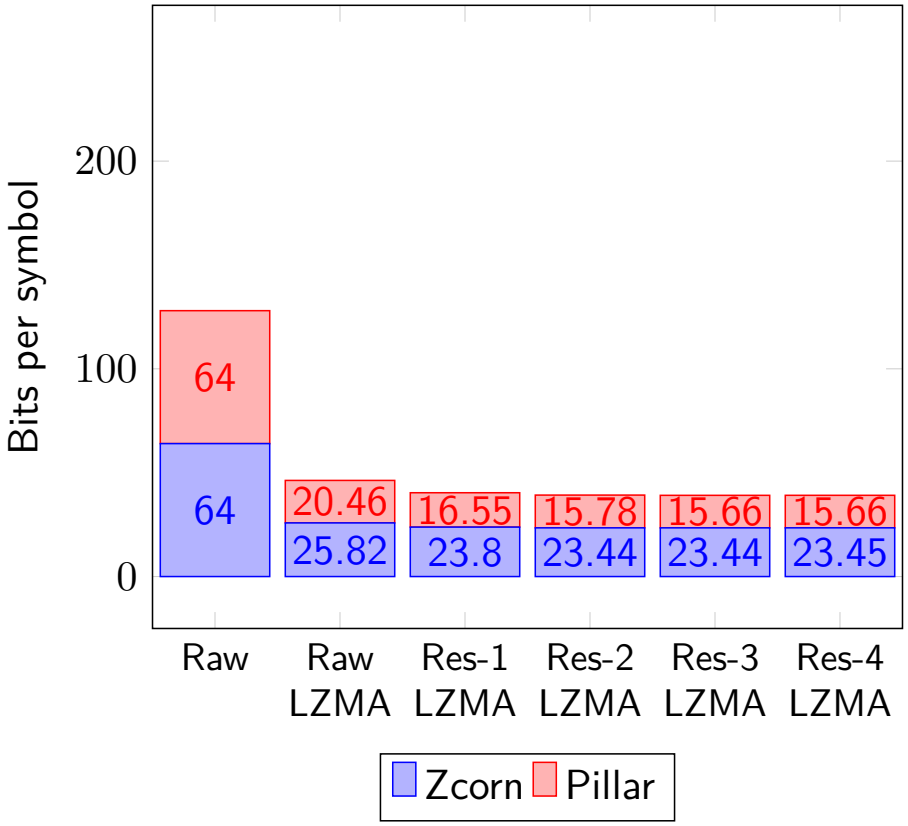
Mesh	Features		Compression rate			
	Faults	File Size	Level	gzip	bzip2	LZMA
1	No	4.62 MB	none	3.73	4.98	6.43
			1	5.62	6.07	7.52
			2–4	5.67	6.12–6.13	7.42–7.44
2	No	42.46 MB	none	3.23	8.41	10.12
			1	6.49	10.82	11.81
			2–6	7.48–7.58	12.75–13.03	13.35
3	Yes	1.46 MB	none	2.67	2.99	3.63
			1	3.88	4.70	5.24
			2–4	4.03–4.05	4.92–4.93	5.47–5.48
4	Yes	7.88 MB	none	1.83	1.89	2.21
			1	2.64	3.06	3.48
			2–4	2.76	3.22–3.23	3.64–3.65
5	Yes	22.73 MB	none	2.46	2.55	3.33
			1	3.14	2.83	3.71
			2–4	3.25–3.26	2.91–2.92	3.80–3.81
6	Yes	274.57 MB	none	2.31	2.25	3.04
			1	3.31	3.53	4.44
			2–6	4.14–4.24	4.48–4.68	5.54–5.73
7	Yes	580.94 MB	none	3.20	5.98	12.52
			1	5.42	7.07	8.90
			2–7	5.80–6.72	7.63–10.12	9.05–10.23

2.2 Comparative performance

All meshes

Mesh	Features		Compression rate			
	Faults	File Size	Level	gzip	bzip2	LZMA
1	No	4.62 MB	none	3.73	4.98	6.43
			1	5.62	6.07	7.52
			2–4	5.67	6.12–6.13	7.42–7.44
		42.46 MB	none	3.23	8.41	10.12
			1	6.49	10.82	11.81
			2–6	7.48–7.58	12.75–13.03	13.35
3	Yes	1.46 MB	none	2.67	2.99	3.63
			1	3.88	4.70	5.24
			2–4	4.03–4.05	4.92–4.93	5.47–5.48
		7.88 MB	none	1.83	1.89	2.21
			1	2.64	3.06	3.48
			2–4	2.76	3.22–3.23	3.64–3.65
5	Yes	22.73 MB	none	2.46	2.55	3.33
			1	3.14	2.83	3.71
			2–4	3.25–3.26	2.91–2.92	3.80–3.81
6	Yes	274.57 MB	none	2.31	2.25	3.04
			1	3.31	3.53	4.44
			2–6	4.14–4.24	4.48–4.68	5.54–5.73
7	Yes	580.94 MB	none	3.20	5.98	12.52
			1	5.42	7.07	8.90
			2–7	5.80–6.72	7.63–10.12	9.05–10.23

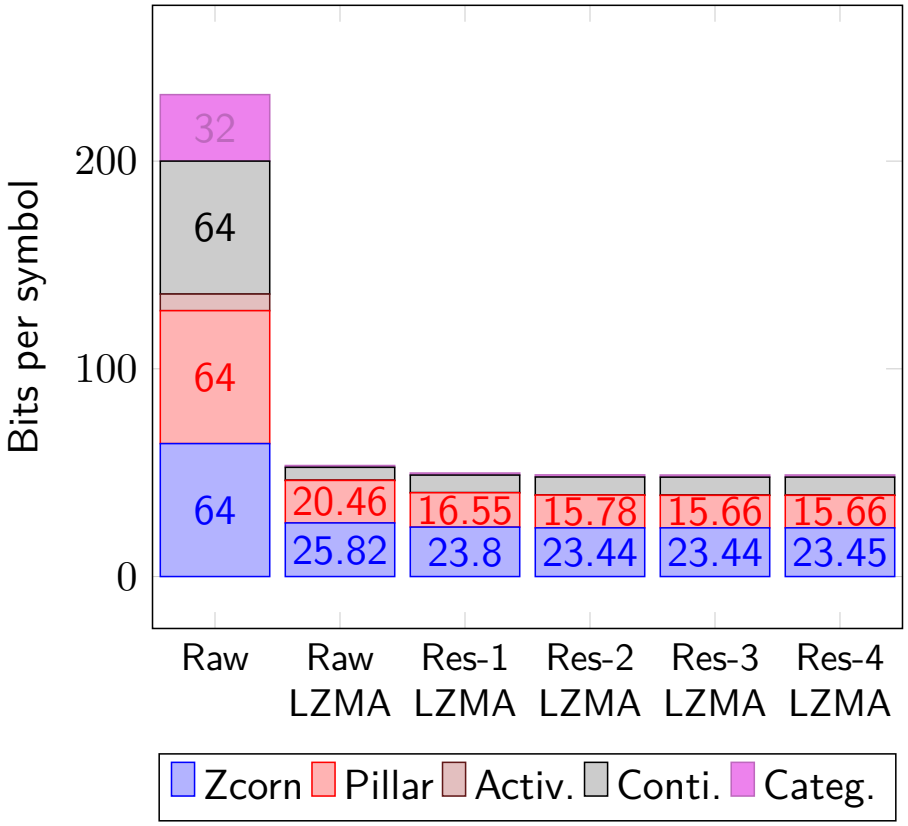
2.3 Compression per mesh component



Results

- Geometry
  - Method efficiency
- Other properties
  - Need for optimization

2.3 Compression per mesh component



Results

- Geometry
  - Method efficiency
- Other properties
  - Need for optimization

Conclusion & future works

Conclusion

- HexaShrink: Efficient lossless compression for Geoscience meshes
  - Coder choice important for best performance & usability
  - Generic lossless coders are not fully adapted to:
    - Multiscale relationships
    - High dynamic data

Future works

- Use multiscale Tree encoders (EZW,SPITH)
- Special treatment of high dynamic data

Conclusion & future works

Conclusion

- HexaShrink: Efficient lossless compression for Geoscience meshes
  - Coder choice important for best performance & usability
  - Generic lossless coders are not fully adapted to:
    - Multiscale relationships
    - High dynamic data

Future works

- Use multiscale Tree encoders (EZW,SPITH)
- Special treatment of high dynamic data

Conclusion & future works

Conclusion

- HexaShrink: Efficient lossless compression for Geoscience meshes
  - Coder choice important for best performance & usability
  - Generic lossless coders are not fully adapted to:
    - Multiscale relationships
    - High dynamic data

Future works

- Use multiscale Tree encoders (EZW,SPITH)
- Special treatment of high dynamic data

Conclusion & future works

Conclusion

- HexaShrink: Efficient lossless compression for Geoscience meshes
  - Coder choice important for best performance & usability
  - Generic lossless coders are not fully adapted to:
    - Multiscale relationships
    - High dynamic data

Future works

- Use multiscale Tree encoders (EZW,SPITH)
- Special treatment of high dynamic data

Conclusion & future works

Conclusion

- HexaShrink: Efficient lossless compression for Geoscience meshes
  - Coder choice important for best performance & usability
  - Generic lossless coders are not fully adapted to:
    - Multiscale relationships
    - High dynamic data

Future works

- Use multiscale Tree encoders (EZW,SPITH)
- Special treatment of high dynamic data

Bibliography:

Jean-Luc. Peyrot, Laurent. Duval, Frédéric. Payan, Lauriane. Bouard, Lénaïc. Chizat, Sébastien. Schneider, and Marc. Antonini.

Hexashrink, an exact scalable framework for hexahedral meshes with attributes and discontinuities: Multiresolution rendering ans strorage of geoscience models.

PREPRINT (Computat. Geosci.), 2018.

Jean-Luc. Peyrot, Laurent. Duval, Sébastien. Schneider, Frédéric. Payan, and Marc. Antonini.

(H)exashrink: Multiresolution compression of large structured hexahedral meshes with discontinuities in geosciences.

In *Proc. Int. Conf. Image Process.*, pages 1101–1105, Phoenix, AZ, USA, Sep. 25-28, 2016.

Patent:

- Method of exploitation of hydrocarbons of an underground formation by means of optimized scaling, US 20170344676

Thank you for your attention!

Innovating for energy

Find us on:

www.ifpenergiesnouvelles.com

@IFPENinnovation