Automatic Generation of Geological Stories from a Single Sketch

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³Total

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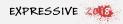
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Geological Soryboards

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Terrains in graphics





• Widely studied in graphics: video games

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Terrains in graphics





• Widely studied in graphics: video games, visualization

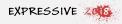
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Terrains in graphics





• Widely studied in graphics: video games, visualization, simulations ...

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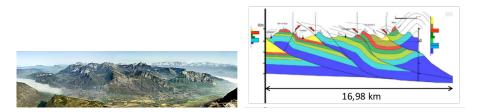
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Terrains in Geology





- Firstly studied in geology: oil extraction, relief evolution, cultural heritage,...
- Study terrain history

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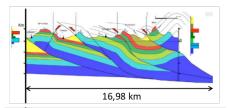
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Goal



- Retrieve terrains history
- Challenge: estimate geological event chronology.
- Use geological sketches analysis (cross section)



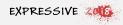
Chartreuse cross-section



Caune de l'Arago cross-section

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Cross Section Problem



- Retrieve cross section history (Geological Events)
- Different kind of events to un-do:
 - sedimentation, compaction, erosion, folding, faulting



Now

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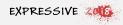
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Cross Section Problem



- Retrieve cross section history (Geological Events)
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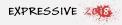


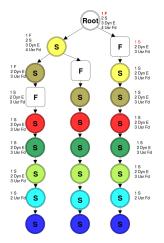
Automatic Generation of Geological Stories from a Single Sketch

- Retrieve all events to undo and partially order them
- Backward simulation using mass-spring systems
- Output: a story tree with all possible scenarios

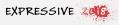
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Output





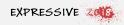
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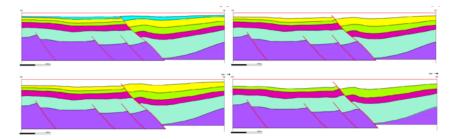


- Geology (Industrial tools):
 - Geometrically-based methods
 - Physically-based methods
- Computer Graphics
 - Sketch-based method

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Tools in Geology: 2D Move





- Manual editing
 - flatten layers, move blocks, remove or add matter
- Preserves geometrical and geological coherence
- Remains labor intensive

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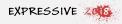
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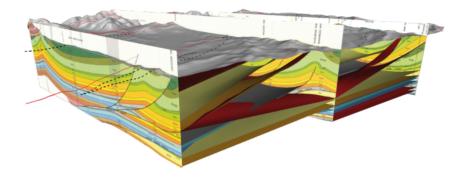
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Extension to 3D: 3D Move





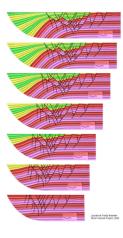
- 3D restoration with vertical cross sections interpolation
- Even more labor intensive !

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Tools in Geology: Physical Simulation





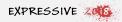
- FEM based physical simulation
- Inverse forces applied to retrieve initial state
- Uncertainties for choosing events to un-do
- Many trials before finding a good solution

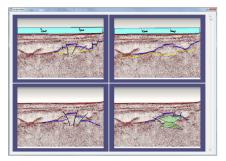
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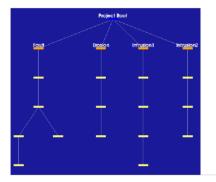
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Tools in graphics: Skecth Based method





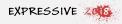


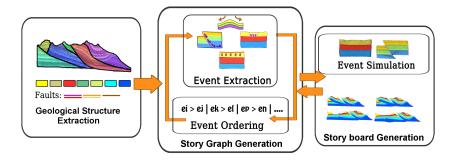
- Superimpose geologists drawing
- Organize them into a story tree
- User has to draw every step

⁰Lidal and al. Geological storytelling. Computers & graphics, 2012 and a storytelling.

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Our Method





- Extract terrain topology (Blocks, Faults) and geological data
- Deduce an event partial order •
- Iterative process for storyboarding: choose event and simulate it イロト イポト イヨト イヨト

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Geological structure extraction



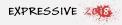
- Vectorial Sketch as input VGC (halfedge like) [Dalstein et al. 2014]
- Topological and Geological data recovery
- Define current section state (sedimentation, eroded unit, faults, etc)

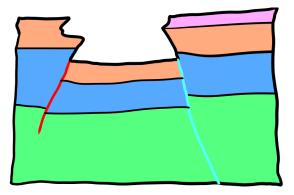
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Event extraction and partial ordering





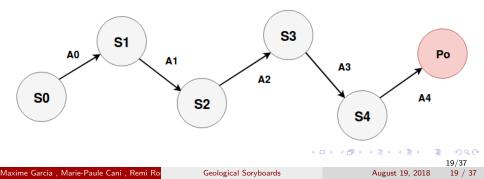
- Events derived from topology and geological information
- Several ordering possibilities
- Partial order using geological rules

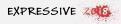
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Partial Ordered Plan (POP)

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- POP: (A, Po, L, Bs)
- A: set of actions leading to P_o
- $a \in A$ can be executed iff pre-conditions are satisfied
- P_o: state goal
- L: Action causal links
- B_s: additionnal constrains





- Extract event from cross section state
- Establish event pre-conditions and consequences on cross section
- Add temporal links (Sedimentation/Erosion, T- jonction faults, etc...)
- Store everything in a Story graph (POP)
- Goal: find event sequences that contain all events.

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Geolgical events pre-conditions and effects

Direct operators	Erode(Unit)	Fold(Block)	Compact(Unit)	FaultAndSlide (Left,Right)	Sediment(Top,Bottom)
Preconditions	Sedimented(Unit), NonEroded(Unit), NonCovered(Unit)	Sedimented(Block), NonFolded(Block)	Sedimented(Unit), Covered(Unit), NonCompacted(Unit)	Sedimented(Left), Sedimented(Right), NonRightFaulted(Left), NonLeftFaulted(Right)	NonSedimented(Top), Sedimented(Bottom), NonCovered(Bottom)
Add	Eroded(Unit)	Folded(Block)	Compacted(Unit)	RightFaulted(Left), LeftFaulted(Right)	Sedimented(Top), NonCovered(Top), NonFrolded(Top), NonCompacted(Top), NonCampacted(Top), NonFaulted(Top), Covered(Bottom)
Delete	Noneroded(Unit)	NonFolded(Block)	NonCompacted(Unit)	NonRightFaulted(Left), NonLeftFaulted(Right)	NonCovered(Bottom)
Inverse operators	Un-Erode(Unit)	Un-Fold(Block)	Un-Compact(Unit)	Un-FaultAndSlide(Left,Right)	Un-Sediment(Top,Bottom)
Preconditions	Sedimented(Unit), NonCovered(Unit), Eroded(Unit)	Sedimented(Block), Folded(Block)	Sedimented(Unit), Covered(Unit), Compacted(Unit)	Sedimented(Left), Sedimented(Right), RightFaulted(Left), LeftFaulted(Right)	Sedimented(Top), Noncovered(Top), NonFolded(Top), NonEroded(Top), NonCompacted(Top), NonFaulted(Top), Covered(Bottom)
Add	NonEroded(Unit)	NonFolded(Block)	NonCompacted(Unit)	NonRightFaulted(Left), NonLeftFaulted(Right)	NonSedimented(Top), NonCovered(Bottom)
Delete	Eroded(Unit)	Folded(Block)	Compacted(Unit)	RightFaulted(Left), LeftFaulted(Right)	Sedimented(Top), Covered(Bottom)

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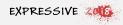
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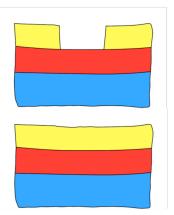
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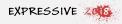
Example: Un-erode

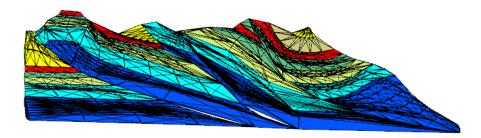




- Condition: Sedimented, Non-Covered, Eroded
- Add: Non Eroded
- Remove: Eroded

Event simulation



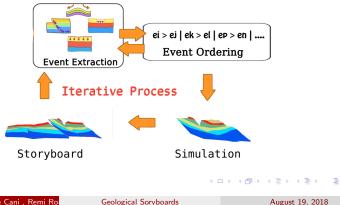


- Mass spring system & Implicit Euler (real-time)
- Discretization along the level boundaries gradient
- Stiching behaviour adding new springs on the fly

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Storyboard generation: Iterative process

- Choose an event whose pre-condition is satisfied
- Run Simulation
- Update Cross section state (new storyboard sketch)
- **Output** Sector \mathbf{O} Continue or backtrack \rightarrow stop when all events are simulated

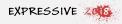


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RESULTS

Caune de l'Arago





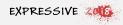
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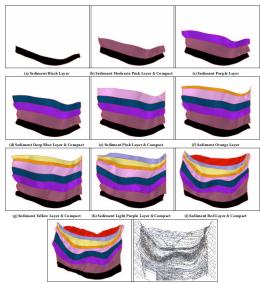
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Results: Caune de l'Arago







(j) Erode Red Layer

(k) Original Sketch

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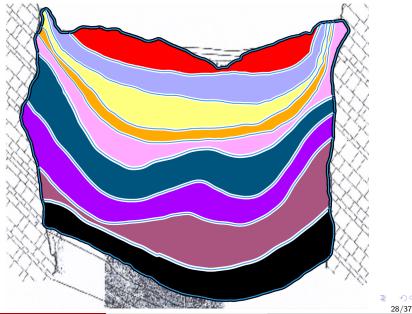
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Results: Caune de l'Arago





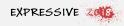
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Tautavel Fields





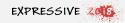
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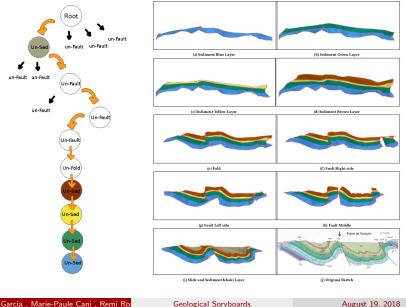
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Results: Tautavel Fields



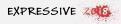


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Chartreuse Mountain

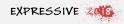


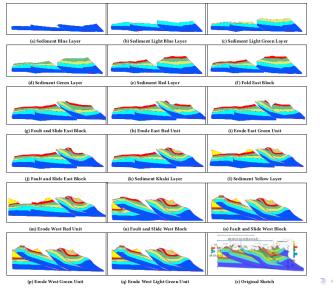


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Results: Chartreuse Storyboard





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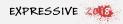
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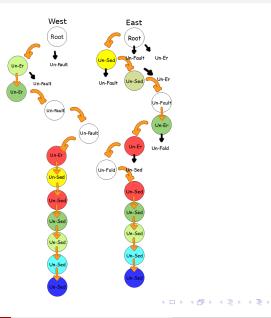
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Results: Chartreuse Story Tree





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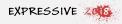
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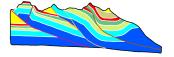
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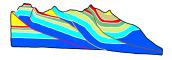
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Results: Chartreuse





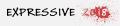


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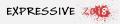
Geological Soryboards



- Automatic storyboard from a single sketch
- Applied mountain history recovering
- Based on automatic event partial ordering
- Backward simulation of geological events using mass-springs model •
- Results validated by geologists

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- This NOT a geological simulation (mass springs to undo events)
- Events are suposed sequentials. Simulate them in paralell !
- More events could be simulated in the future
- Use VAC [Dalstein et al. 2015] for space time interpolation
- Extension to 2.5D and 3D

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THANK YOU!

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