

Automatic Generation of Geological Stories from a Single Sketch

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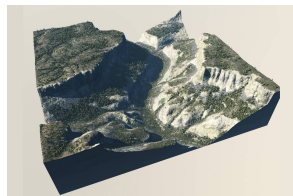
August 19, 2018



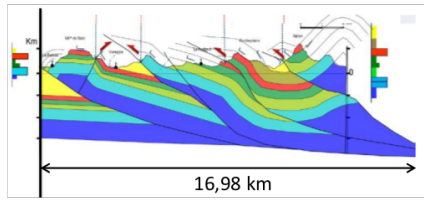
- Widely studied in graphics: video games



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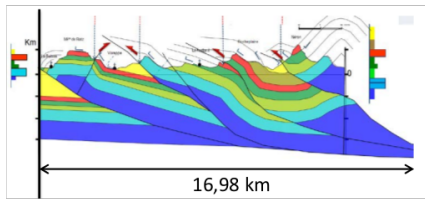


- Widely studied in graphics: video games, visualization, simulations ...

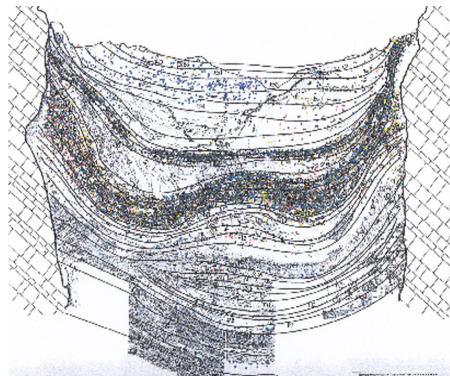


- Firstly studied in geology: oil extraction, relief evolution, cultural heritage,...
- Study terrain history

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

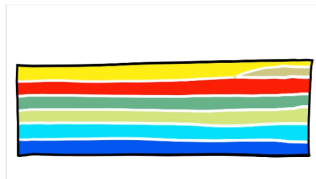


Chartreuse cross-section

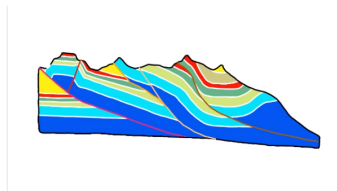


Caune de l'Arago cross-section

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

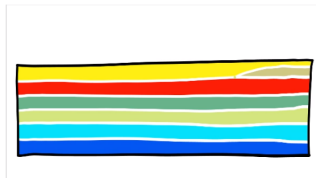


Before

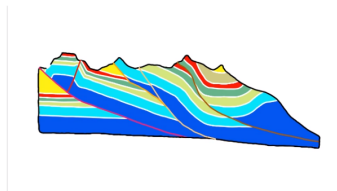


Now

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



Before

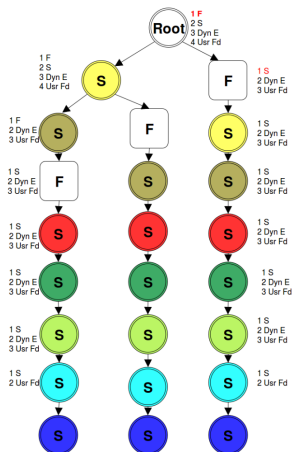


Now

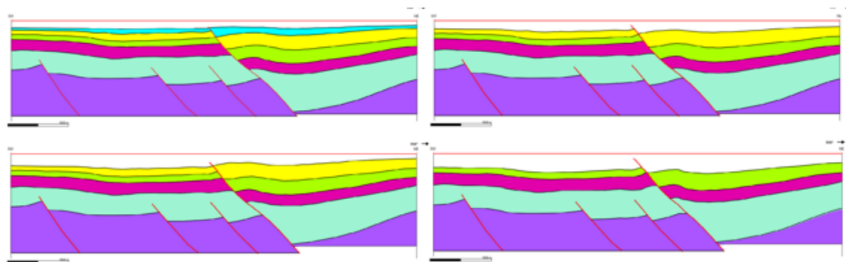
Automatic Storyboarding

Automatic Generation of Geological Stories from a Single Sketch

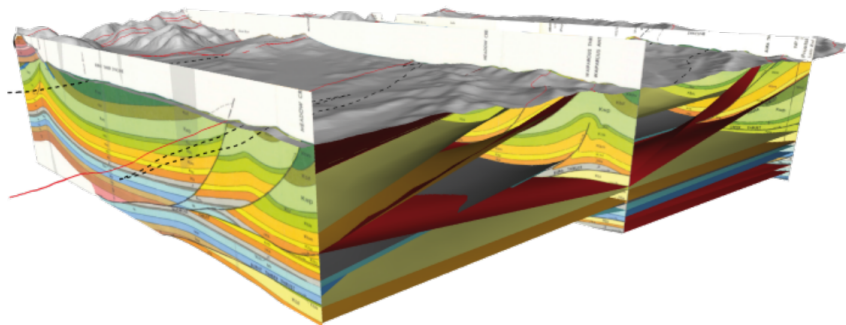
- Retrieve all events to undo and partially order them
- Backward simulation using mass-spring systems
- Output: a story tree with all possible scenarios



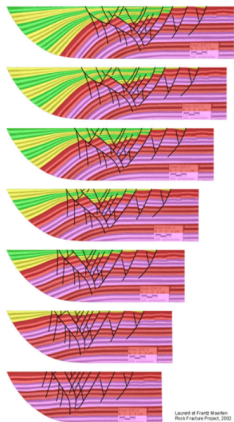
- Geology (Industrial tools):
 - ▶ Geometrically-based methods
 - ▶ Physically-based methods
- Computer Graphics
 - ▶ Sketch-based method



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

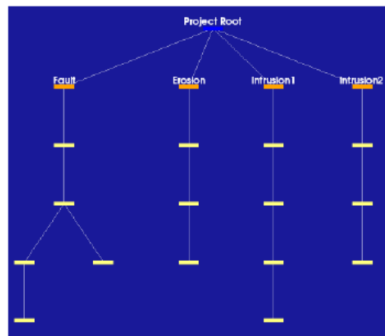
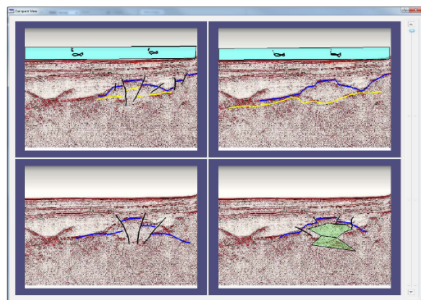


- 3D restoration with vertical cross sections interpolation
- Even more labor intensive !



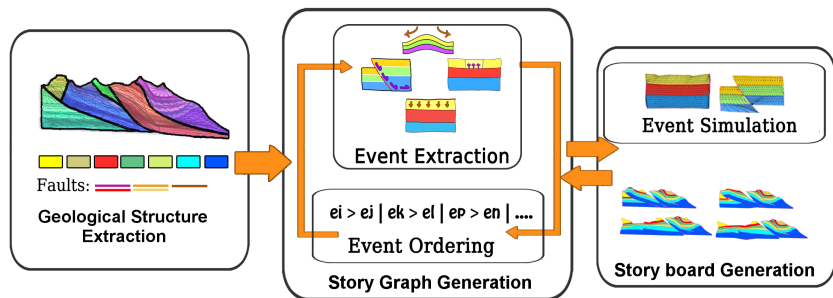
Laurent et Françoise Maréchal
Rock Fracture Project, 2002

- 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

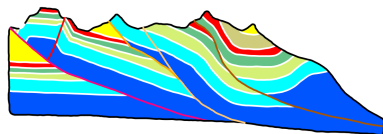
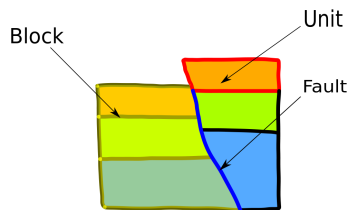


- Superimpose geologists drawing
- Organize them into a story tree
- User has to draw every step

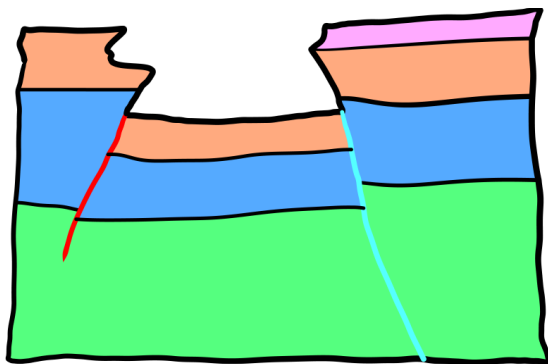
⁰Lidal and al. Geological storytelling. Computers & graphics, 2012



- Extract terrain topology (Blocks, Faults) and geological data
- Deduce an event partial order
- Iterative process for storyboarding: choose event and simulate it

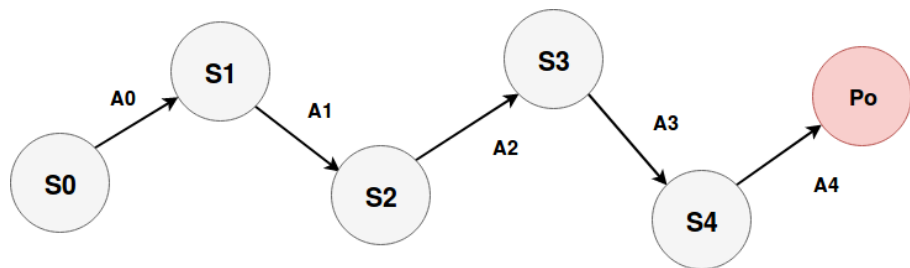


- Vectorial Sketch as input VGC (halfedge like) [Dalstein et al. 2014]
- Topological and Geological data recovery
- Define current section state (sedimentation, eroded unit, faults, etc)



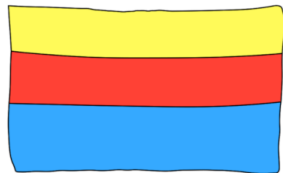
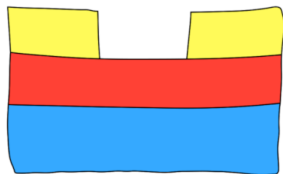
- Events derived from topology and geological information
- Several ordering possibilities
- Partial order using geological rules

- POP: (A, P_o, L, B_s)
- 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 : additional constrains

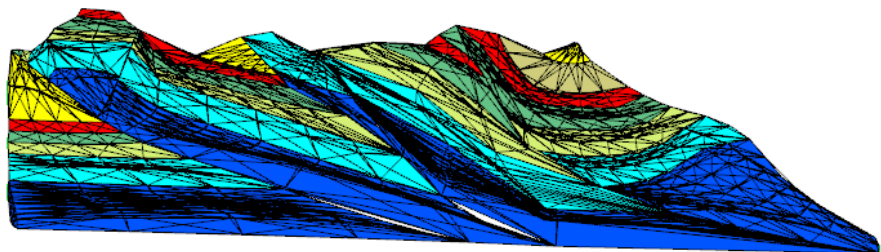


- Extract event from cross section state
- Establish event pre-conditions and consequences on cross section
- Add temporal links (Sedimentation/Erosion, T- junction faults, etc...)
- Store everything in a Story graph (POP)
- Goal: find event sequences that contain all events.

| 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), NonFolded(Top), NonEroded(Top), NonCompacted(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) |

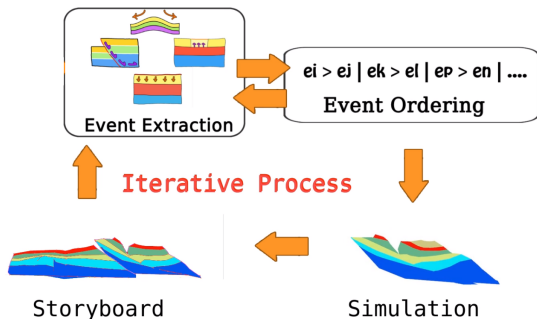


- Condition: Sedimented, Non-Covered, Eroded
- Add: Non Eroded
- Remove: Eroded



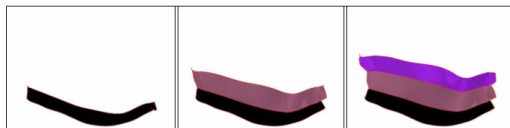
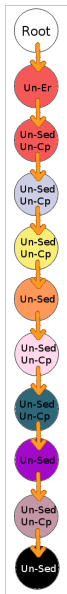
- Mass spring system & Implicit Euler (real-time)
- Discretization along the level boundaries gradient
- Sticking behaviour adding new springs on the fly

- 1 Choose an event whose pre-condition is satisfied
- 2 Run Simulation
- 3 Update Cross section state (new storyboard sketch)
- 4 Continue or backtrack → stop when all events are simulated

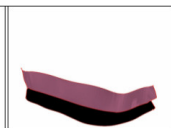


RESULTS

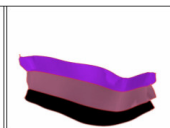




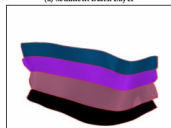
(a) Sediment Black Layer



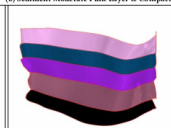
(b) Sediment Moderate Pink Layer & Compact



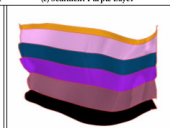
(c) Sediment Purple Layer



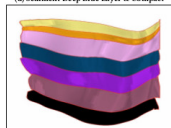
(d) Sediment Deep Blue Layer & Compact



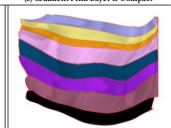
(e) Sediment Pink Layer & Compact



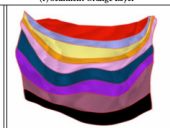
(f) Sediment Orange Layer



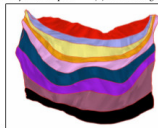
(g) Sediment Yellow Layer & Compact



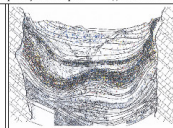
(h) Sediment Light Purple Layer & Compact



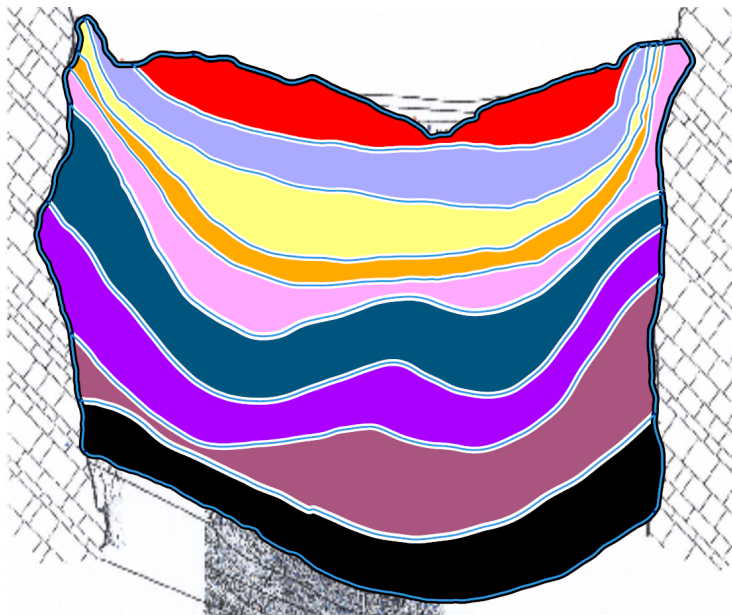
(i) Sediment Red Layer & Compact



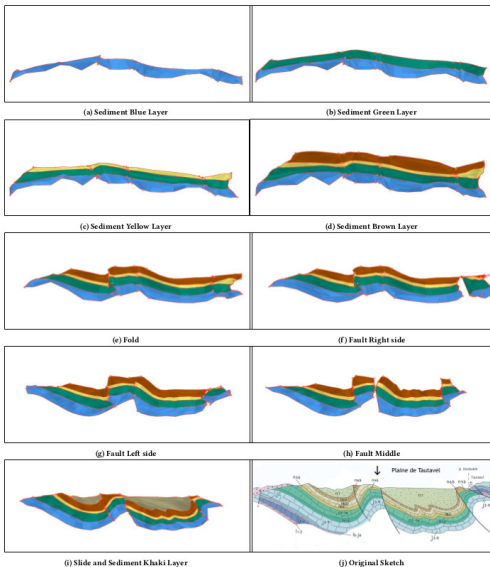
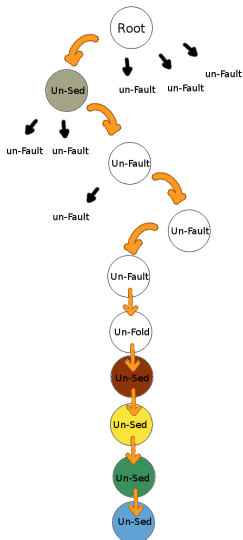
(j) Erode Red Layer



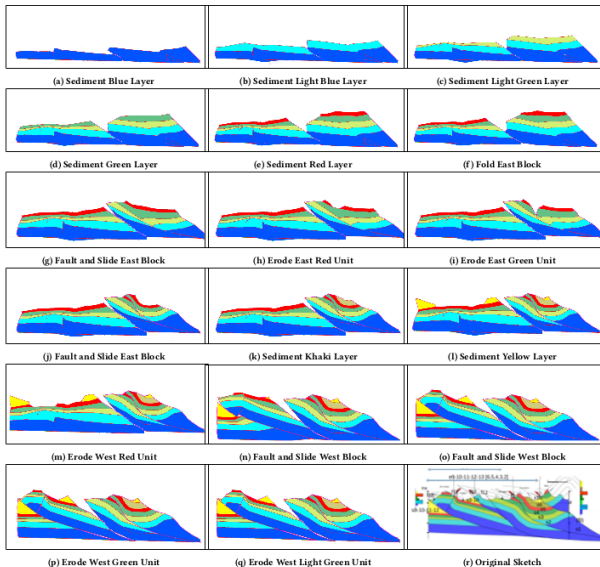
(k) Original Sketch



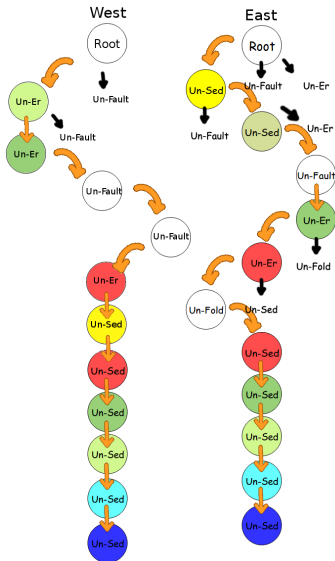


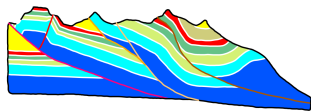
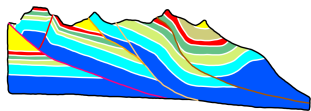






Results: Chartreuse Story Tree





- 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

- This NOT a geological simulation (mass springs to undo events)
- Events are supposed 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

THANK YOU!