Parametric Surfaced-Based Geological Reservoir Representation

A Computer Graphics Tool for Improved Decision Making in Immersive Environments

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Parametric Surfaced Based Modeling

Because reservoir modelling is conventionally started from a predefined grid, surfaced based modeling have not been used widely in this context (Jacquemyn et al.2018).

In fact, using 2D surfaces of 3D solid objects is a typical representation of 3D models. Two of the major ways for surface representation in computer graphics are implicit representations and parametric surface representations. Parametric surface representations, unlike implicit representations, are based on control points.

Manipulating these control points makes it easy and intuitive to modify geological models smoothly and fast, with a potential to more interactive decision-making.
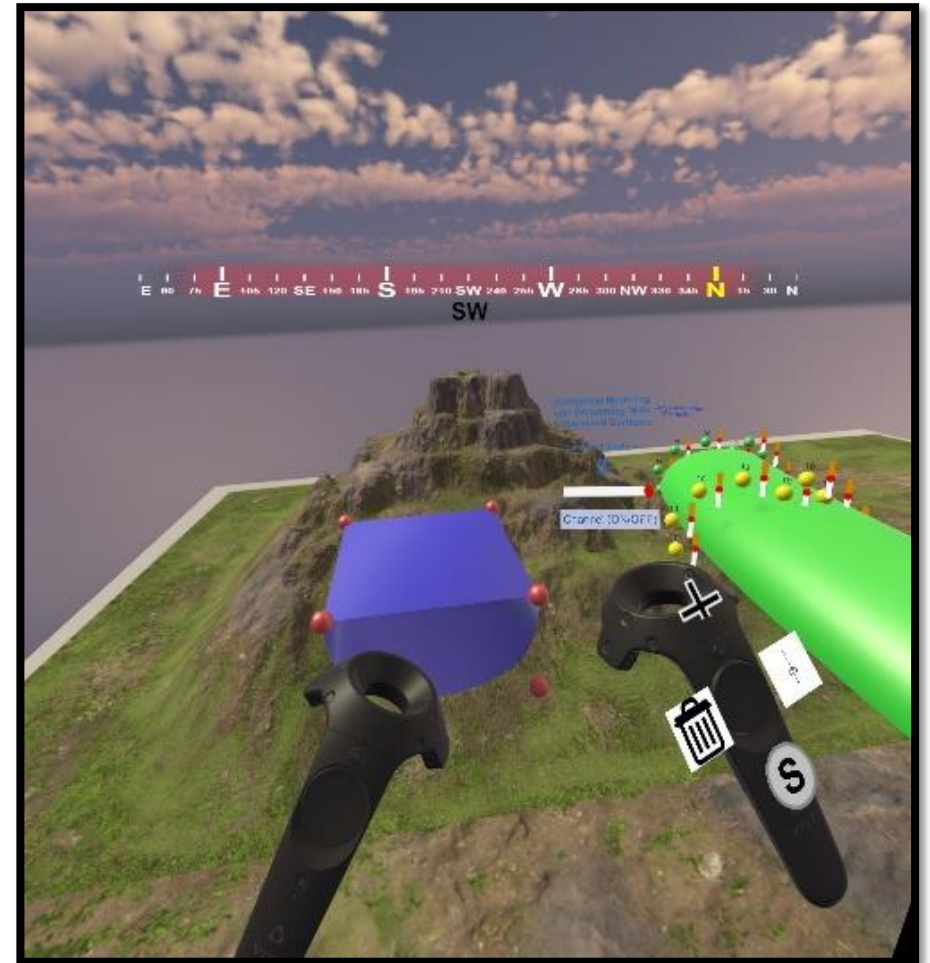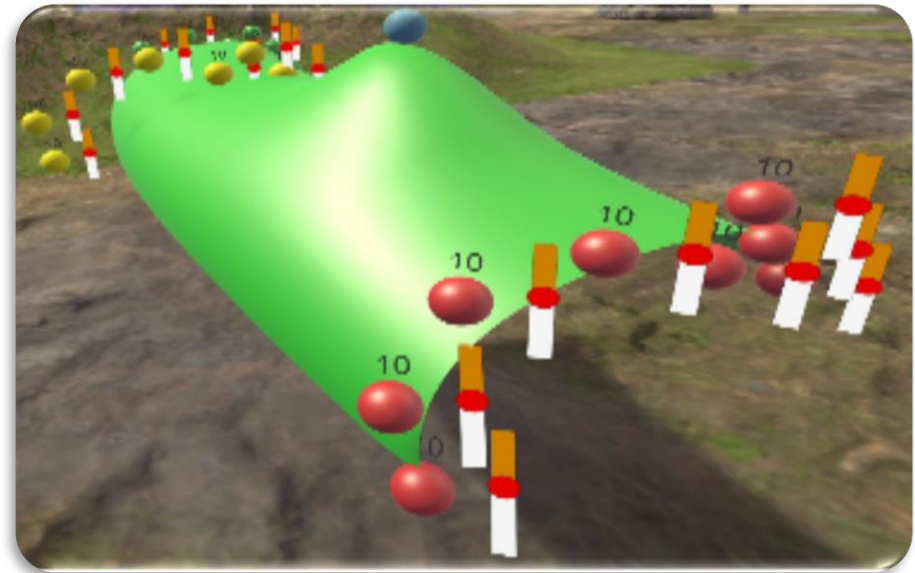
Methods

1) **NURBS:** Spline surfaces, e.g. Bezier or NURBS surfaces, are a popular and common standard for CAD (Computer-Aided Design). Also, these surfaces are on the basis of parametric- based curves and a set of weighted control points.

$$C(u) = \sum_{i=1}^{k} \frac{N_{i,n} w_i}{\sum_{j=1}^{k} N_{j,n} w_j} \mathbf{P}_i = \frac{\sum_{i=1}^{k} N_{i,n} w_i \mathbf{P}_i}{\sum_{i=1}^{k} N_{i,n} w_i}$$

Research Question: Is the NURBS always the best option for explicit modelling?

Making NURBS Surface in Unity game engine for VR

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Problems of the NURBS

1) Using a single NURBS surface is limited for the representation of the surfaces like a sheet, a cylinder or a torus (Derose et all 1998) and many NURBS patches should be used to create the complex geometry model (Watertight Model). (Polygon Mesh Processing book, Botch et al 2010)

2) Trimming NURBS is expensive and often has numerical errors. (Polygon Mesh Processing book, Botch et al 2010)

3) Adding more control points is only possible by splitting parameter interval. (Polygon Mesh Processing book, Botch et al 2010)

Probably, we may fix these problems by some tricks, But what Computer Graphics says?

Especially if you want to work with real time Virtual Reality and you need the updated model fast

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Methods

2) Subdivision Surfaces: Subdivision Surfaces define smooth surfaces after a series of refinement which can be controlled by control points. Subdivision surfaces are not only a popular method for making free form models but also a common tool in animation, computer games and entertainment industry.
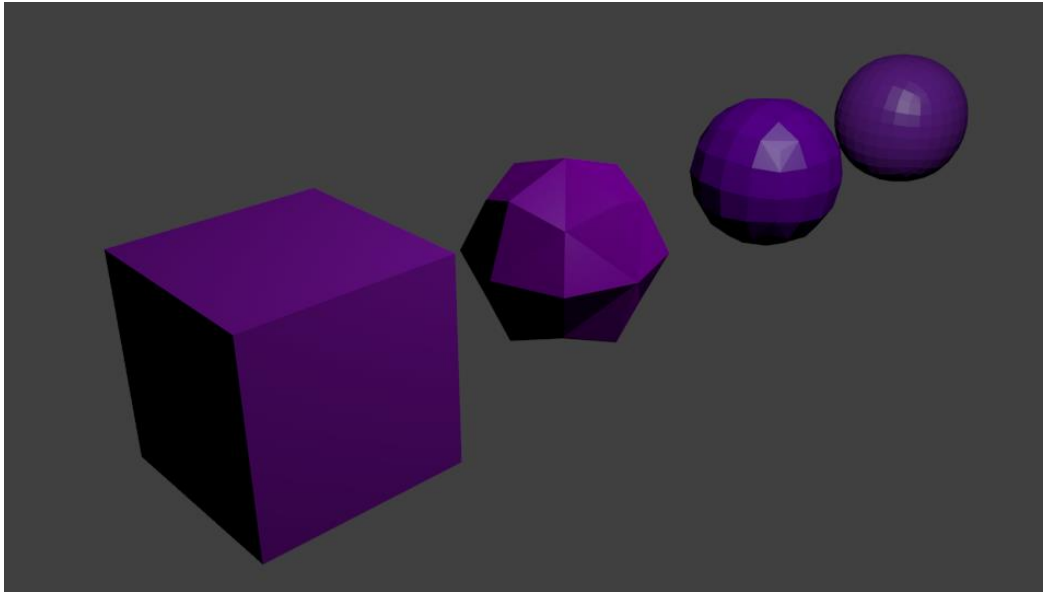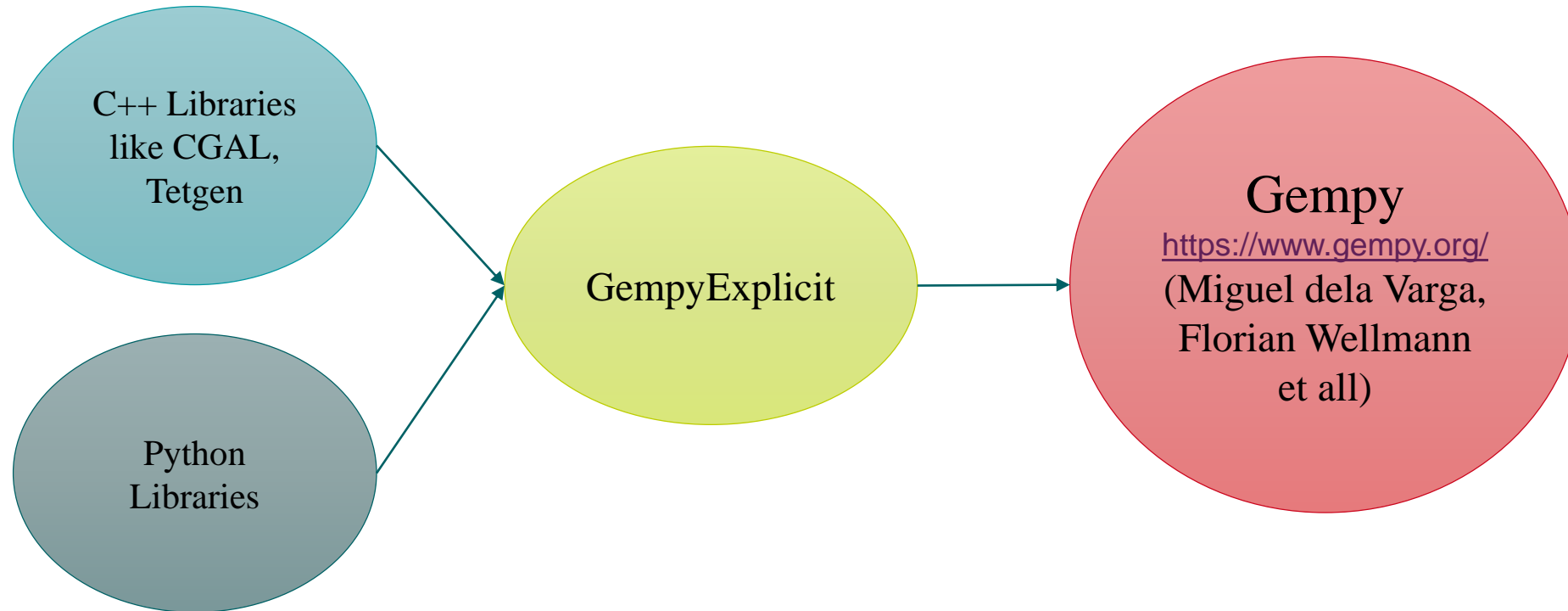

Subdivision surfaces procedure
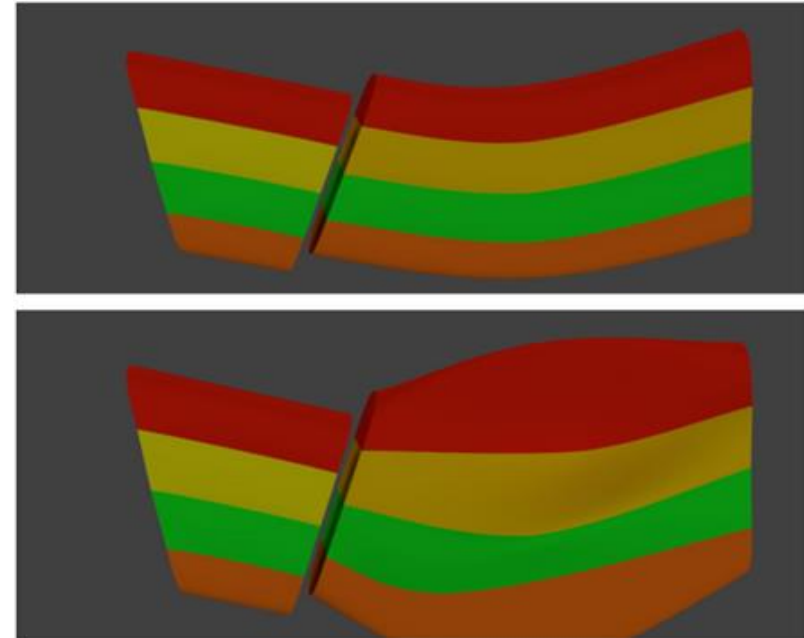
Layered structure by subdivision surfaces

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GempyExplicit

Python package for explicit geological modeling which can support C++ and python libraries


```
gempyExplicit.NURBS_Surface(3,5,knot1,knot2,Control_Points,Weights, 50,50,"auto",False)
```
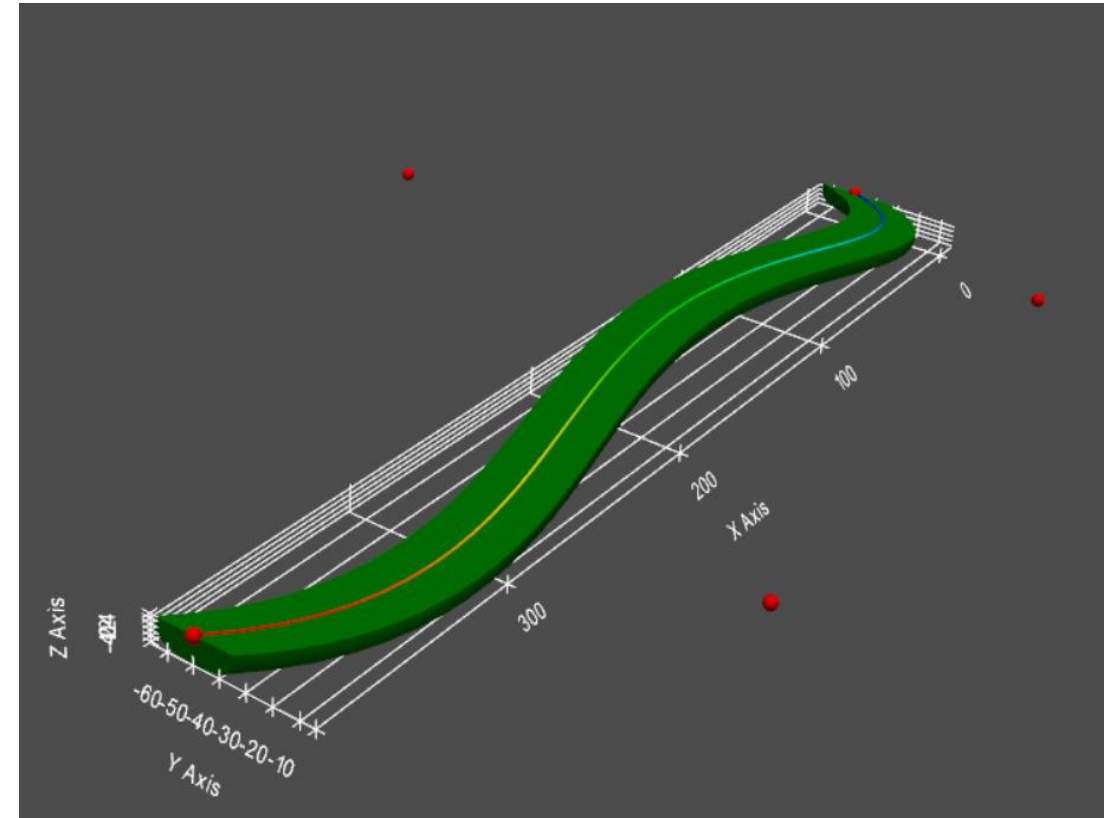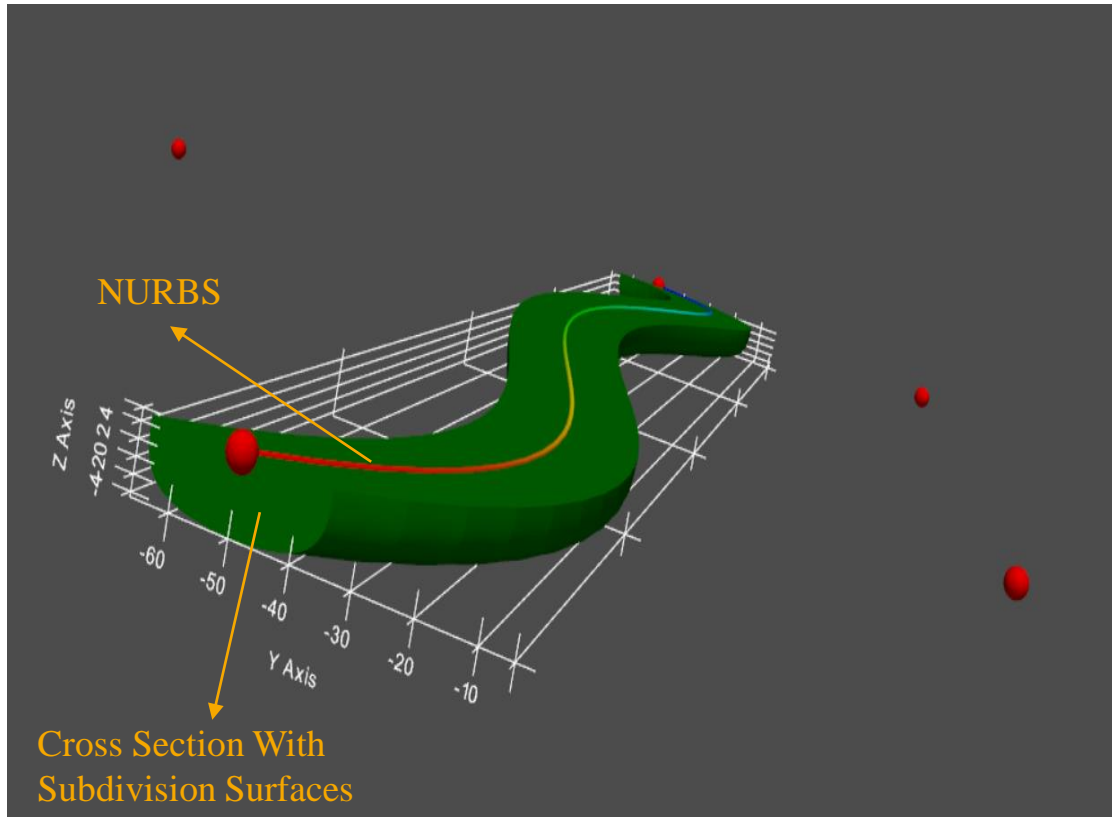NURBS Surface

```
gempyExplicit.Subdiv(mesh,5,"kobbelt","cgal")
```
Five times smoothing with $\sqrt{3}$– subdivision (Leif Kobbelt) method by CGAL engine

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Explicit Modeling by GempyExplicit (Combination of NURBS (for longitudinal section) and Subdivision Surfaces (cross section)

In Subdivision surfaces method, we start with the closed and watertight model and gradually try to convert it to our goal shape (here channel). Because of starting with a watertight model at first, the model will be watertight at the end.
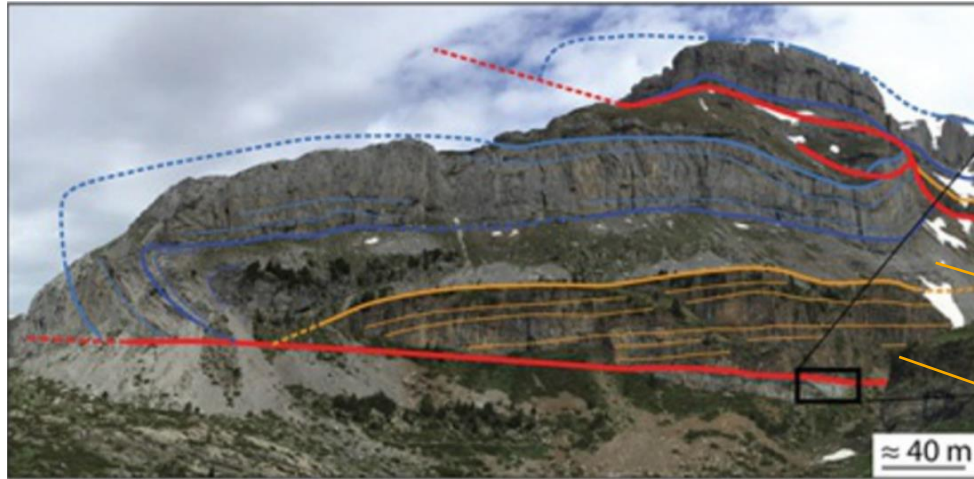

NURBS

Cross Section With
Subdivision Surfaces

Explicit Modeling by GempyExplicit (Combination of NURBS and Subdivision Surfaces)

To make the model more flexible, we used the NURBS as longitude controller and subdivision surfaces for cross section. With this method, two channels can be combined together and controlled easily.
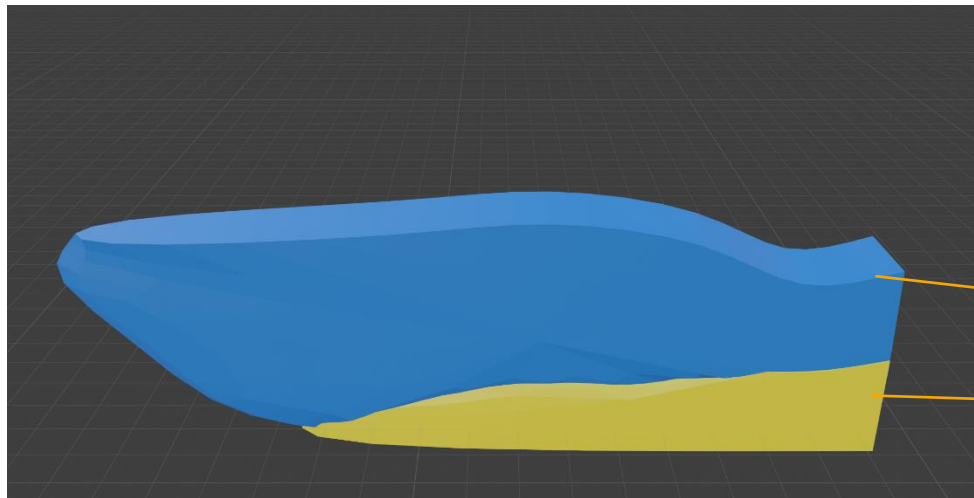
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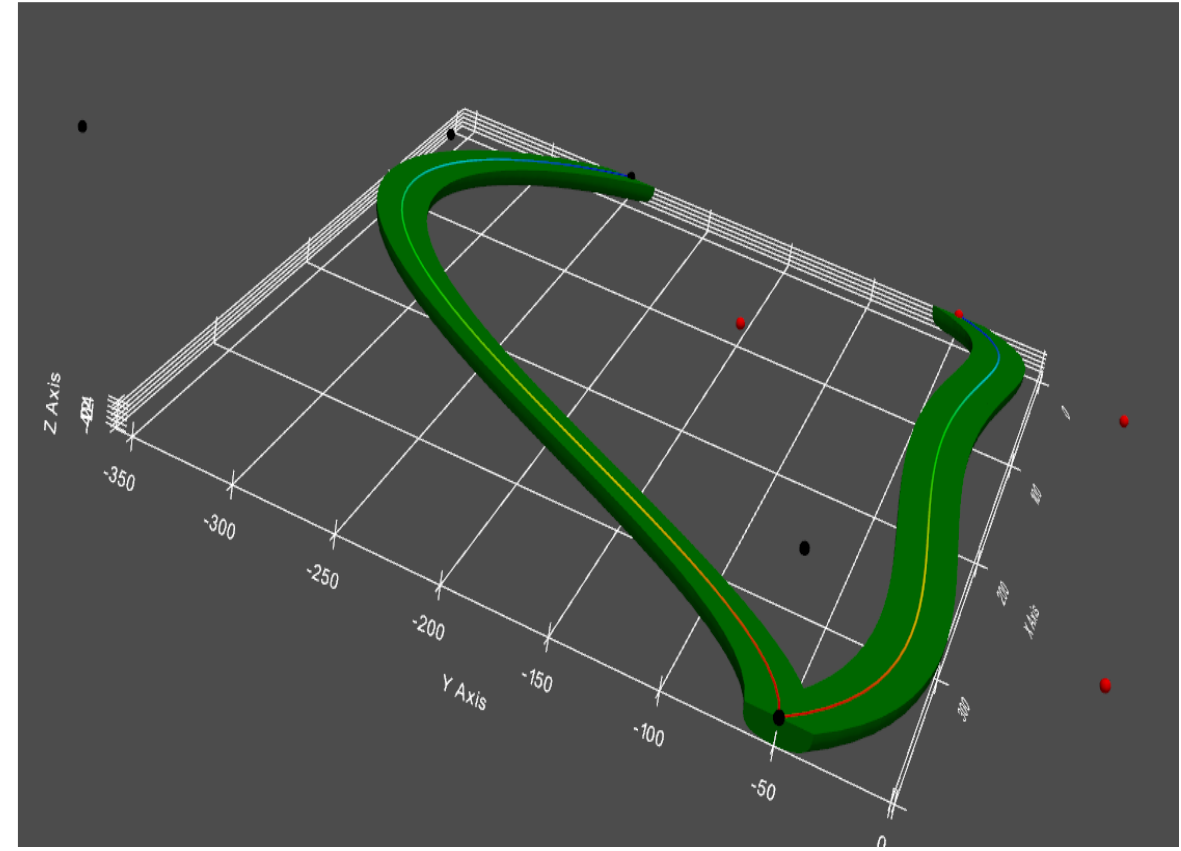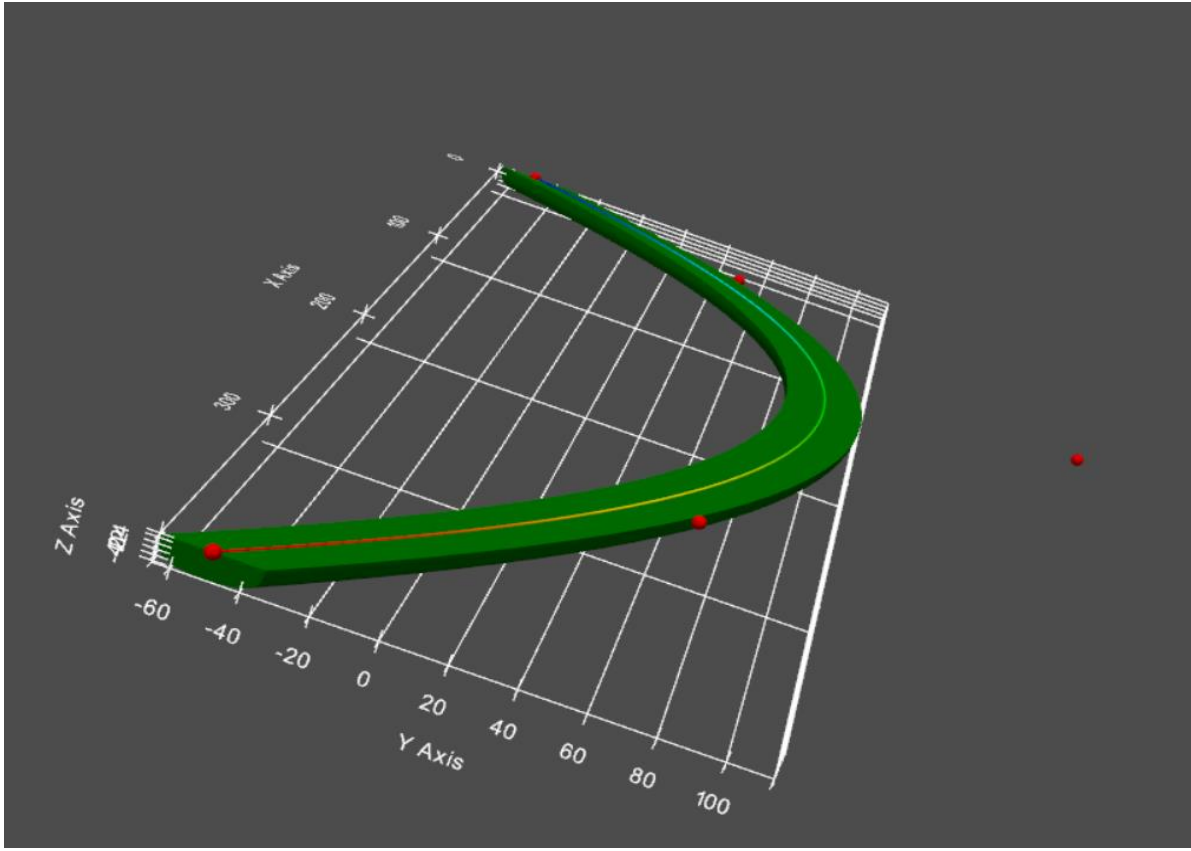
Complex Geological Structures by Subdivision Surfaces

(Wellmann and Caumon 2018)

Dolomit

Sandstone

Control Points
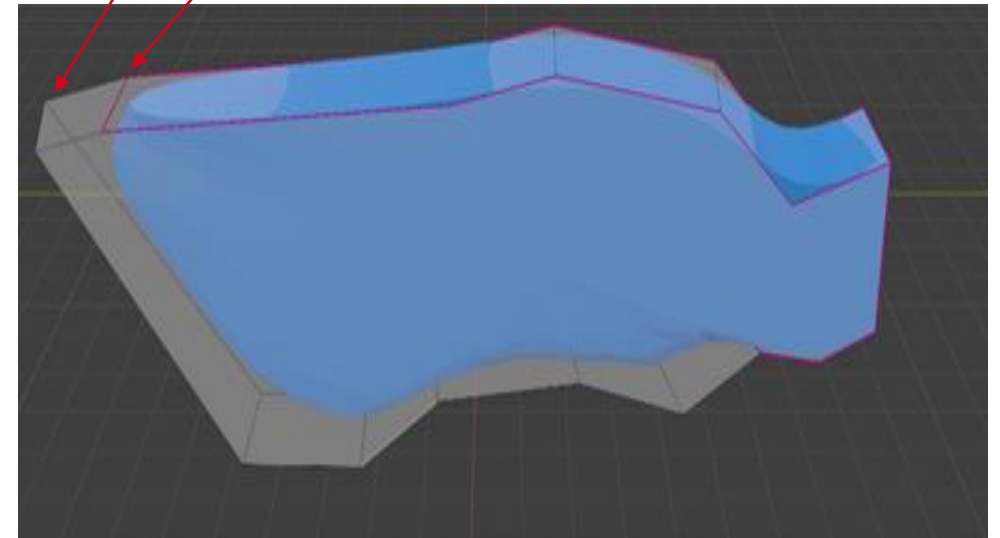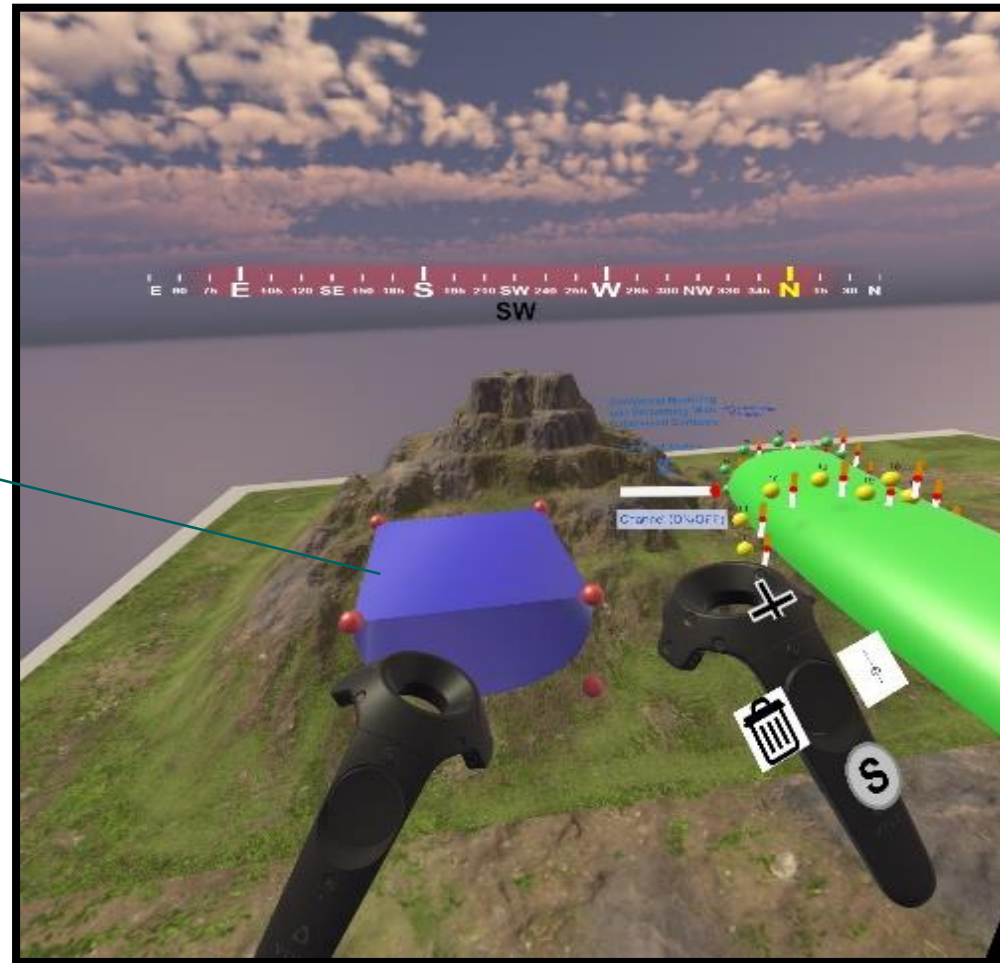
Dolomit

Sandstone

Subdivision Surfaces and NURBS models in Virtual Reality

small channel in VR by subdivision surfaces with control points

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Conclusion

Recently, research has been done based on using spline surfaces to model diverse geological structures and reservoirs. Similar to applications in computer graphics, using these methods in geological modelling can have specific considerations.

Model refinement (e.g. adding new control points) and the requirement of many patches with geometrical constraints for the representation of complex geometries are some of the main difficulties of using spline surfaces (NURBS). In this presentation, we presented these aspects and showed promising and controllable technique (Subdivision Surfaces)for intuitive use of parametric surface-based representations in 3D geological and reservoir modelling.

NURBS and Subdivision surfaces, both are the common techniques for explicit modelling and each of them has it's own negative and positive features. Both of these methods can be used by GempyExplicit. Its core mostly is based on C++ codes and libraries like CGAL which are wrapped to the python.

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