Visualisation avec VTK

EPITA - 13/06/2025 – Roman Fenioux

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Visualisation?

Qu’est ce que VTK?

- **Une bibliothèque de visualisation**
  - Implémentée en utilisant les principes de programmation orienté objet
  - Codée en C++ (5M LOC), basé sur OpenGL
  - Automatiquement wrappé en Java, Tcl et Python ainsi que .Net (ActiViz)
  - Portable: Unix, Windows, MacOSX, mobile devices
  - Supporte 2D/3D visualisation, traitement d’image, rendu volumique, infoviz et geoviz
  - Environ 2500+ personnes sur les listes de diffusion
  - Utilisé par beaucoup d’industriels et académiques
  - Libre (BSD-like license)

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Statistiques de VTK (openhub)

In a Nutshell, Visualization Toolkit...

... has had 73,044 commits made by 536 contributors
representing 5,650,305 lines of code

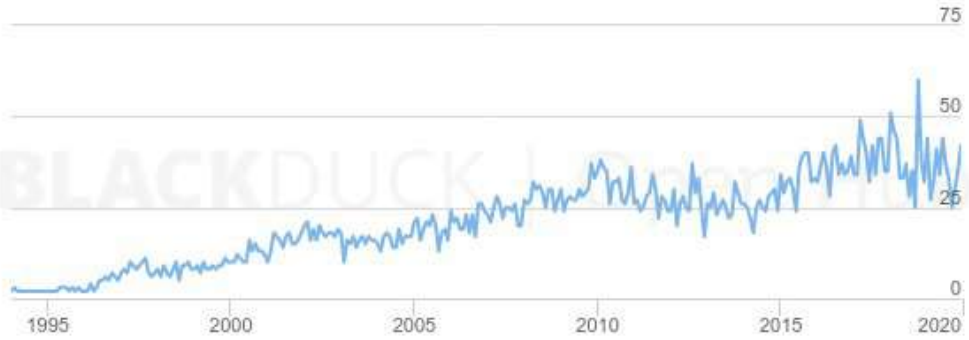
... is mostly written in C++
with an average number of source code comments

... has a well established, mature codebase
maintained by a very large development team
with stable Y-O-Y commits

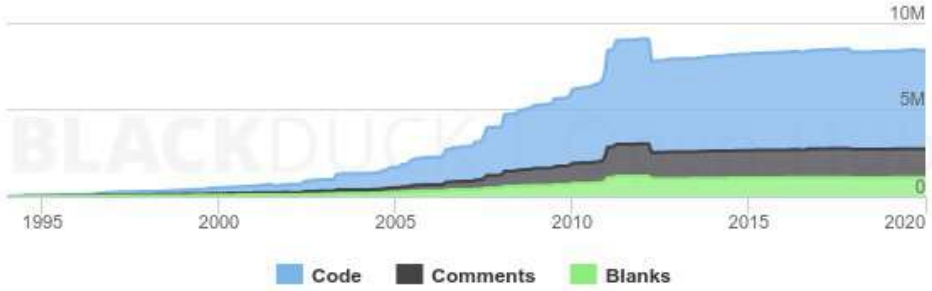
... took an estimated 1,727 years of effort (COCOMO model)
starting with its first commit in January, 1994
ending with its most recent commit about 2 months ago

Community

Contributors per Month



Lines of Code



30 Day Summary
Dec 15 2019 — Jan 14 2020

229 Commits
41 Contributors
including 5 new contributors

12 Month Summary
Jan 14 2019 — Jan 14 2020

3298 Commits
Up + 77 (2%) from previous 12 months

123 Contributors
Down -20 (13%) from previous 12 months

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Philosophie du design de VTK

- **Architecture ouverte afin de créer des programmes (pas de UI)**
- **Architecture modulaire: chaque module fait une chose (correctement)**
  - Modules implémentés en utilisant de la programmation objets
  - Pipeline: les données passent par les modules
- **VTK a plusieurs thèmes**
  - Traitement de données
  - Interagir avec les données
  - Support pour les données massives

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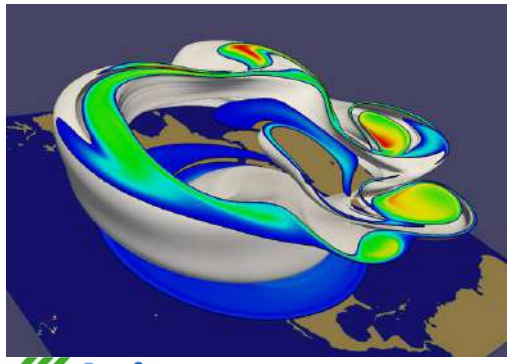
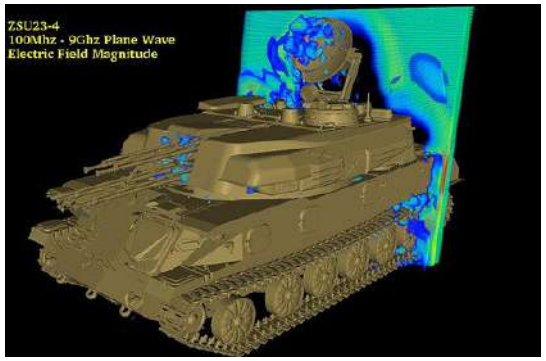
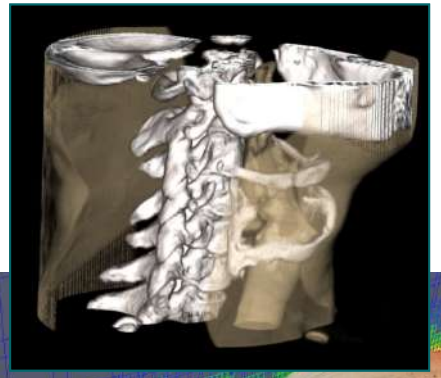
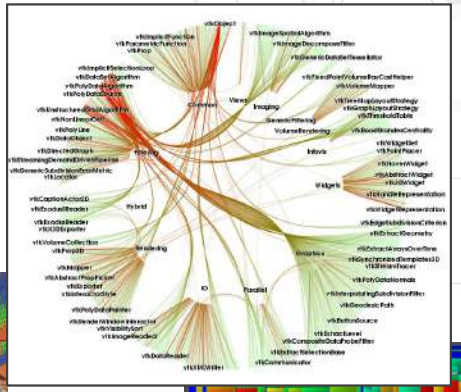
Que puis-je faire avec VTK?

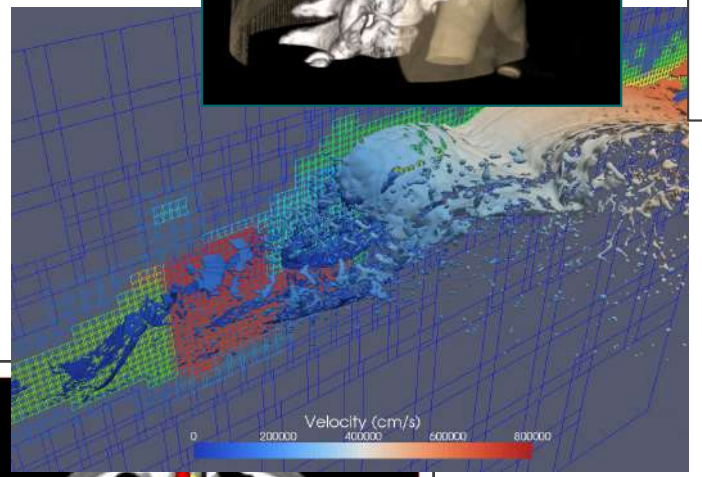
- **Visualisation Scientifique**
  - 0D: Visualisation d'information
  - 2D: Graphs/
  - 3D/4D: traitement de données et rendu
  - Traitement d'image
  - Rendu volumique

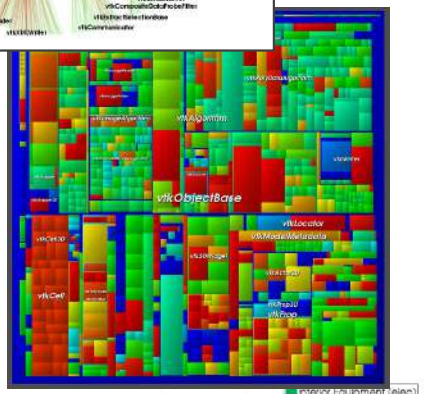


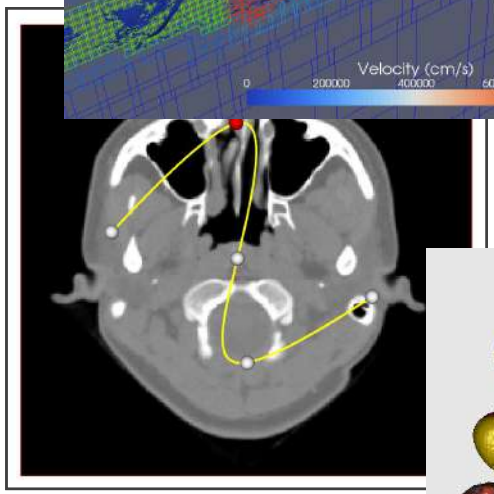


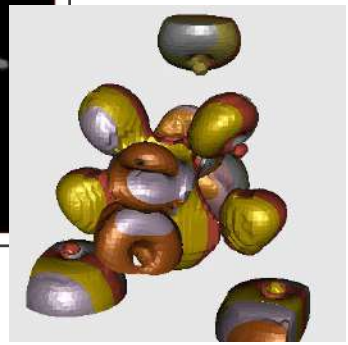


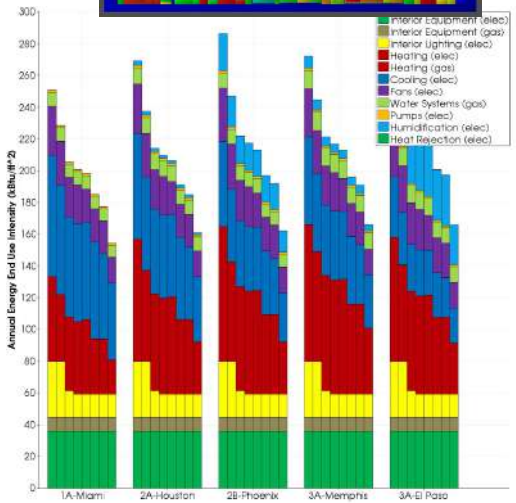












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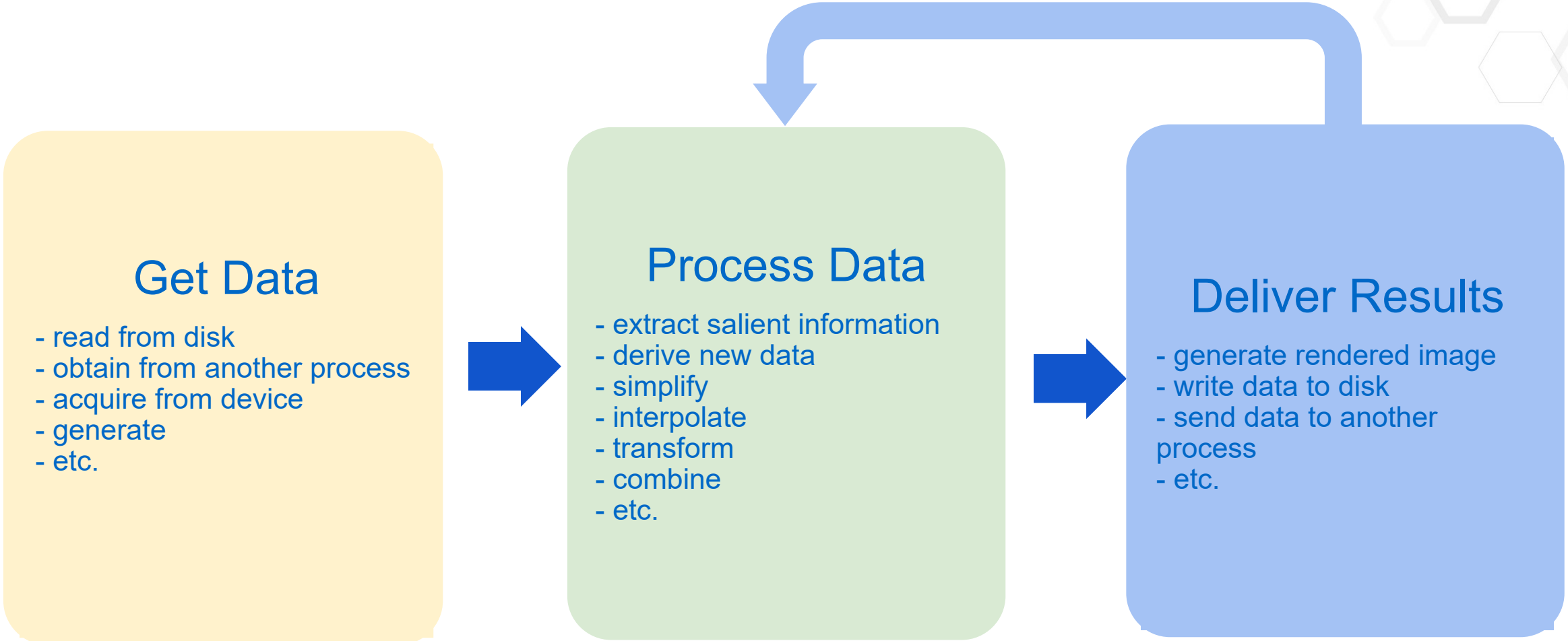
Visualisation



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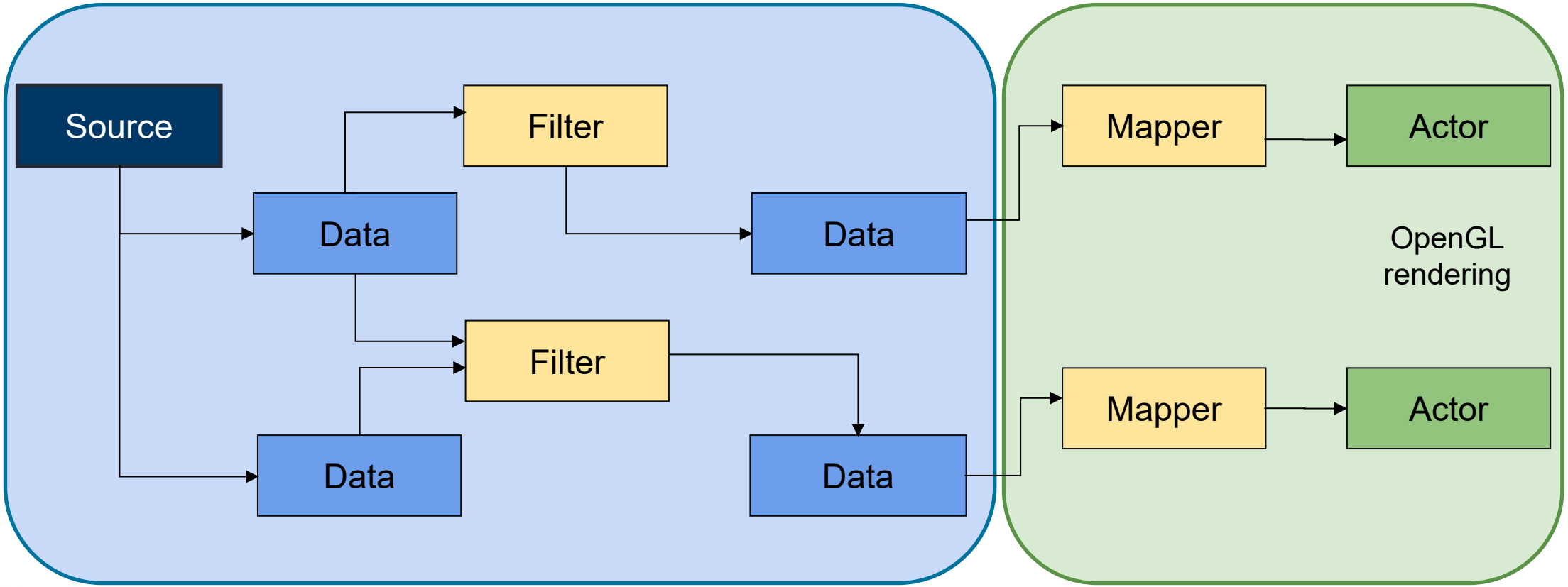
Architecture du pipeline de VTK

Une séquence d'algorithme qui opèrent sur des données.



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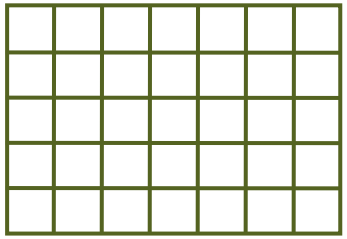
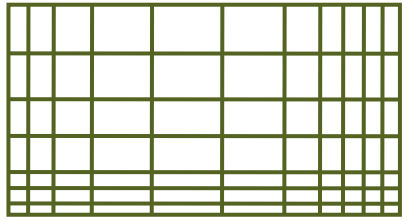
Type de données dans VTK

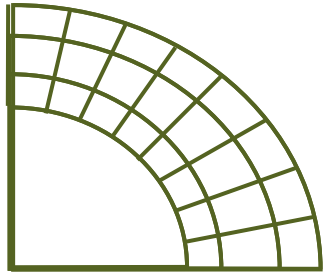
vtkImageData



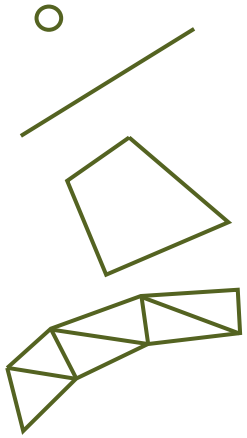
vtkRectilinearGrid



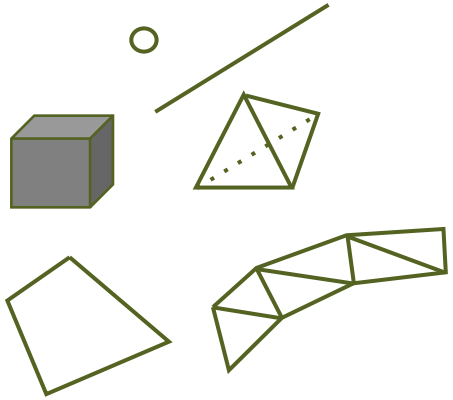
vtkStructuredGrid



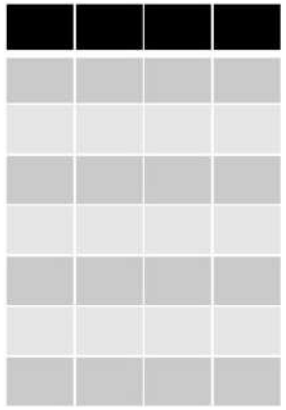
vtkPolyData



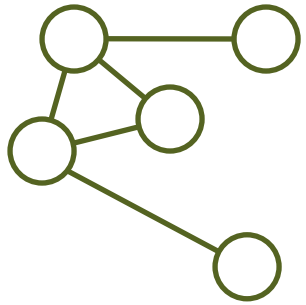
vtkUnstructuredGrid



vtkTable



vtkGraph



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VTK Object Modeling Diagram

vtkObject

inherits from

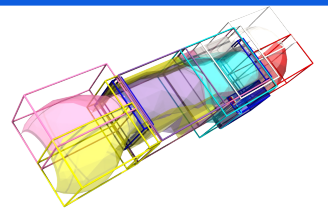
vtkDataObject

Name	Capitol	Population
California	Sacramento	
Texas	Austin	
…	…	…

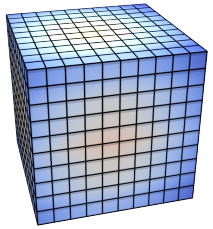
vtkTable

vtkDataSet

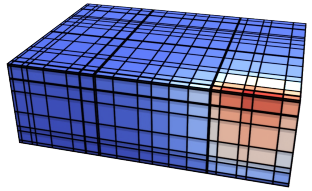
vtkCompositeDataObject



vtkImageData

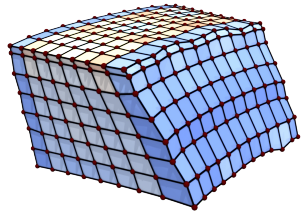


vtkRectilinearGrid

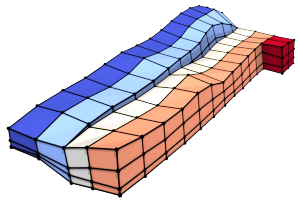


vtkPointSet

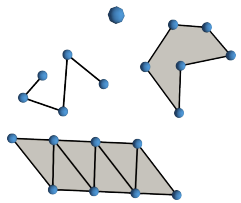
vtkStructuredGrid



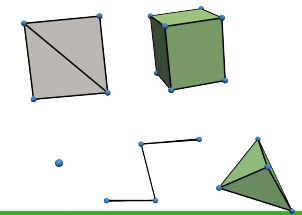
vtkExplicitStructuredGrid



vtkPolyData



vtkUnstructuredGrid



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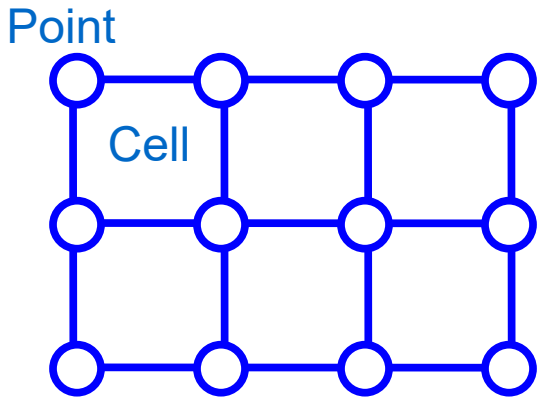
Type de données dans VTK

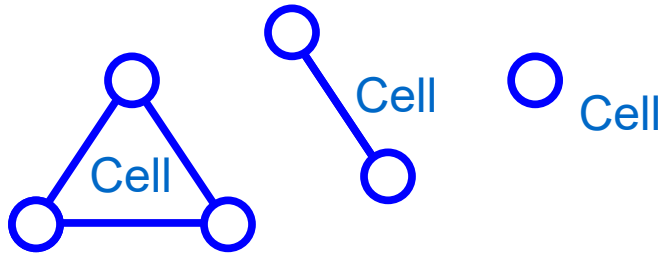
- **vtkDataObject: représente un « blob »de données**
  - Superclasses de tous les types de VTK
  - Aucune structure géométrique ou topologique
- **vtkDataSet: représente une donnée avec une géométrie et topologie**
  - Contient une géométrie (points) et une topologies (cellules)
  - Possède des attributs associées au points et aux cellules
- **vtkDataArrays: représente les attributs**
  - Ints, floats, chars, strings, variants, etc…

Structure Spatiale

- **Points (nœuds)**
  - Tableau de coordonnées x, y, z
- **Cellules**
  - Types et liste de points



Structured Data



Unstructured Data

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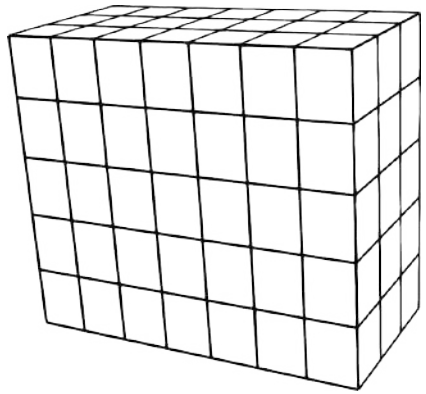
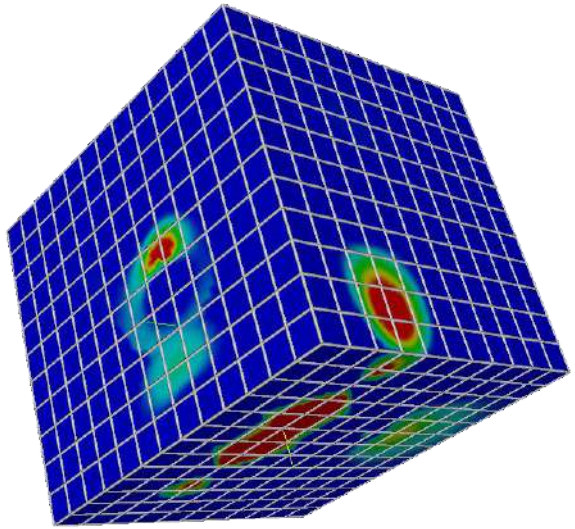
vtkImageData

- **Uniforme et rectilinéaire**
  - La géométrie et topologie sont implicite
  - Définie par un origin, dims et spacing





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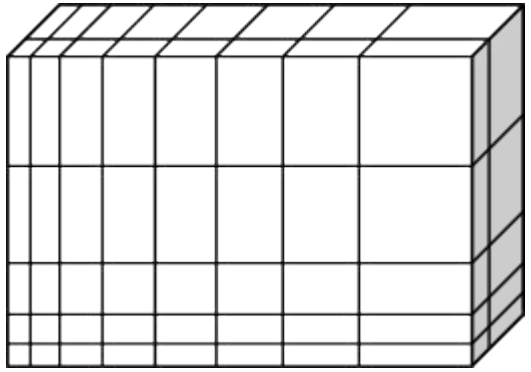
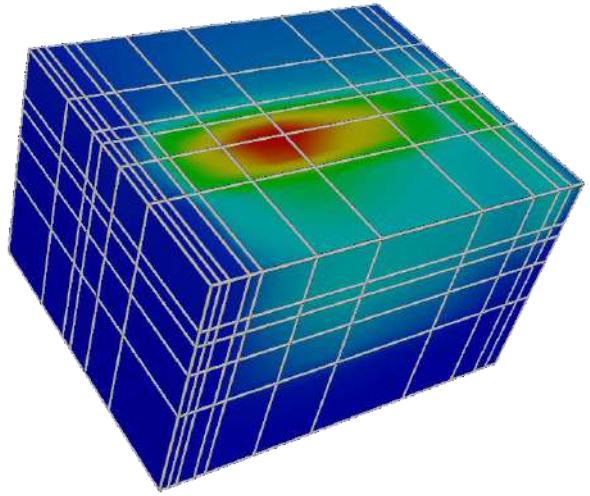
vtkRectilinearGrid

- **Non-uniforme mais rectilineaire**
  - La géométrie et topologie sont implicite
  - Définie par un origin, dims et spacing dans toutes les dimensions





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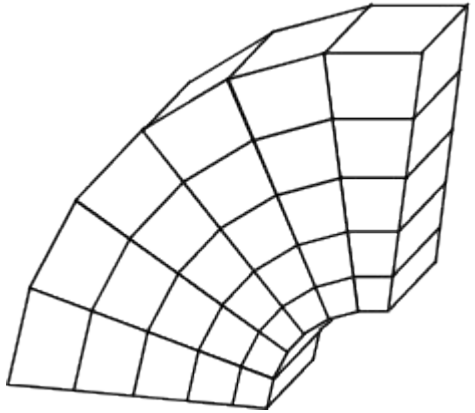
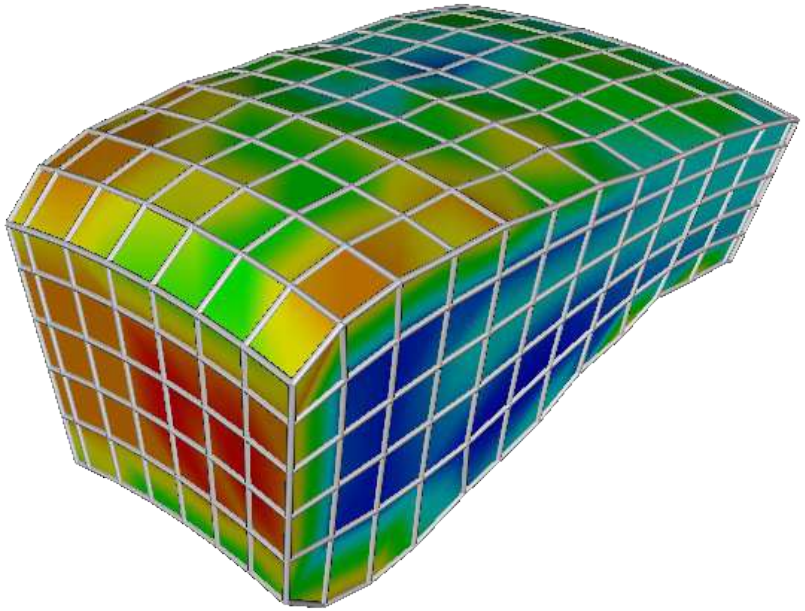
vtkStructuredGrid

- **Non-uniforme et curvilinéaire**
  - La géométrie est explicite et définie par des points
  - La topologie est implicite: les cellules peuvent être accéder par (i,j,k)





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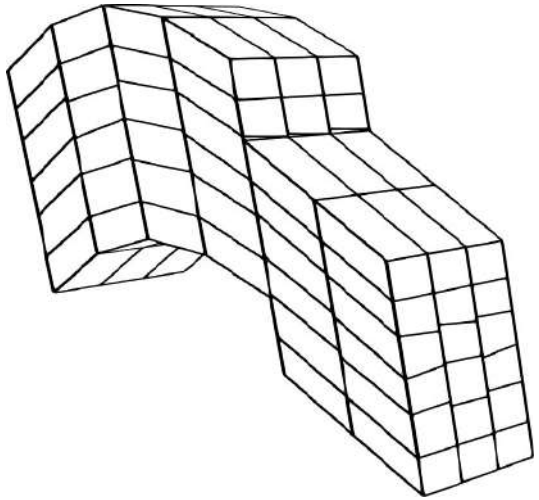
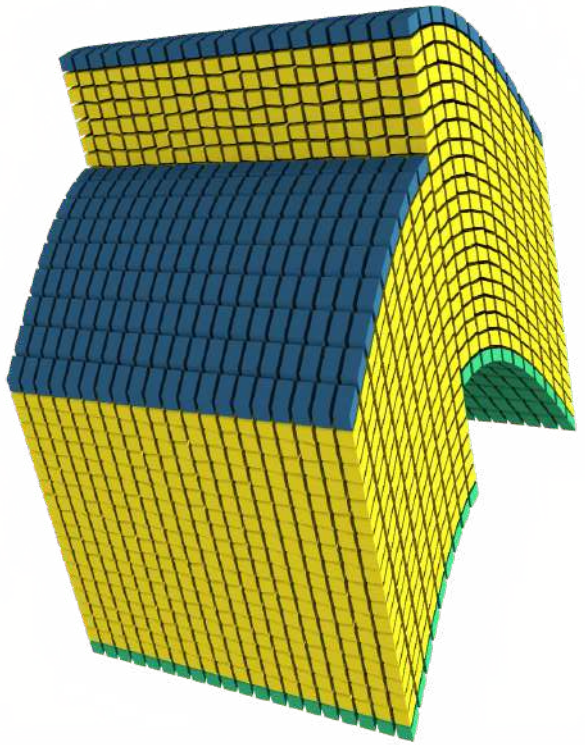
vtkExplicitStructureGrid

- **Non-uniforme et explicite**
  - Tableau d’hexaèdres
  - Les voisins ne partages pas nécessairement une face





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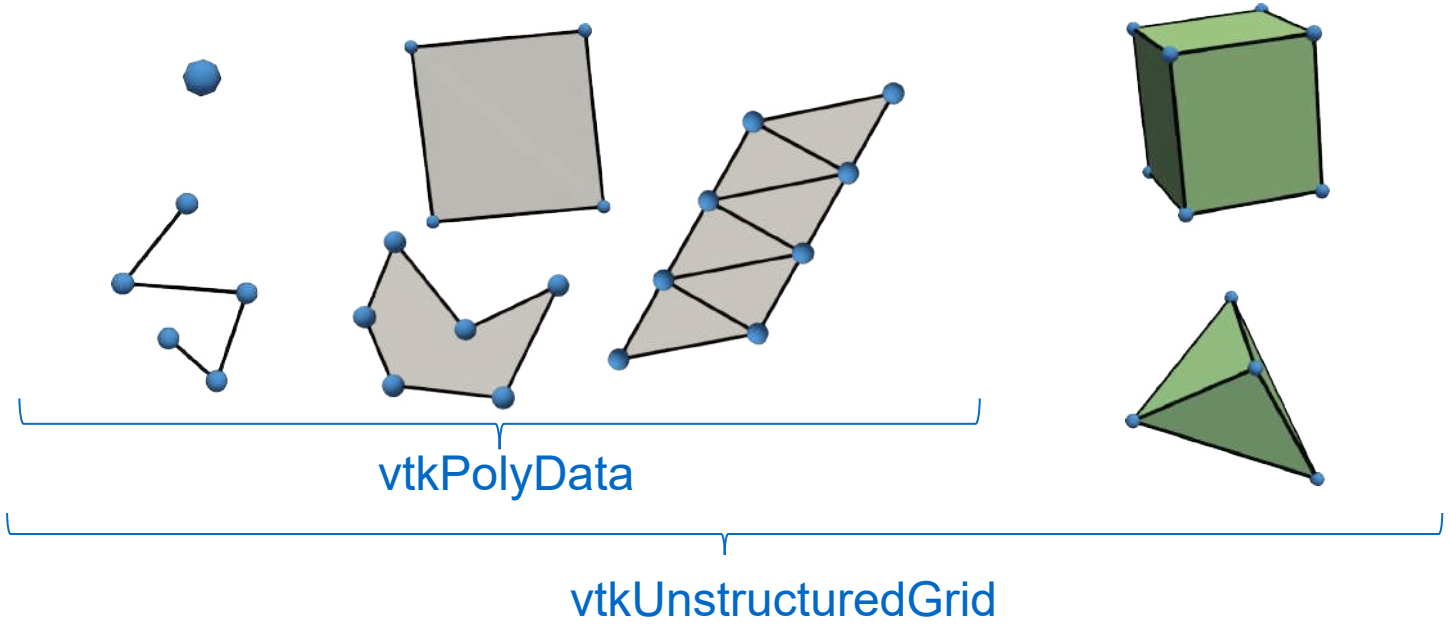
vtkPolyData et vtkUnstructuredGrid

- **Données non structurées**
  - La géométrie est explicite et définie par des points
  - La topologie est explicite et définie par des cellules



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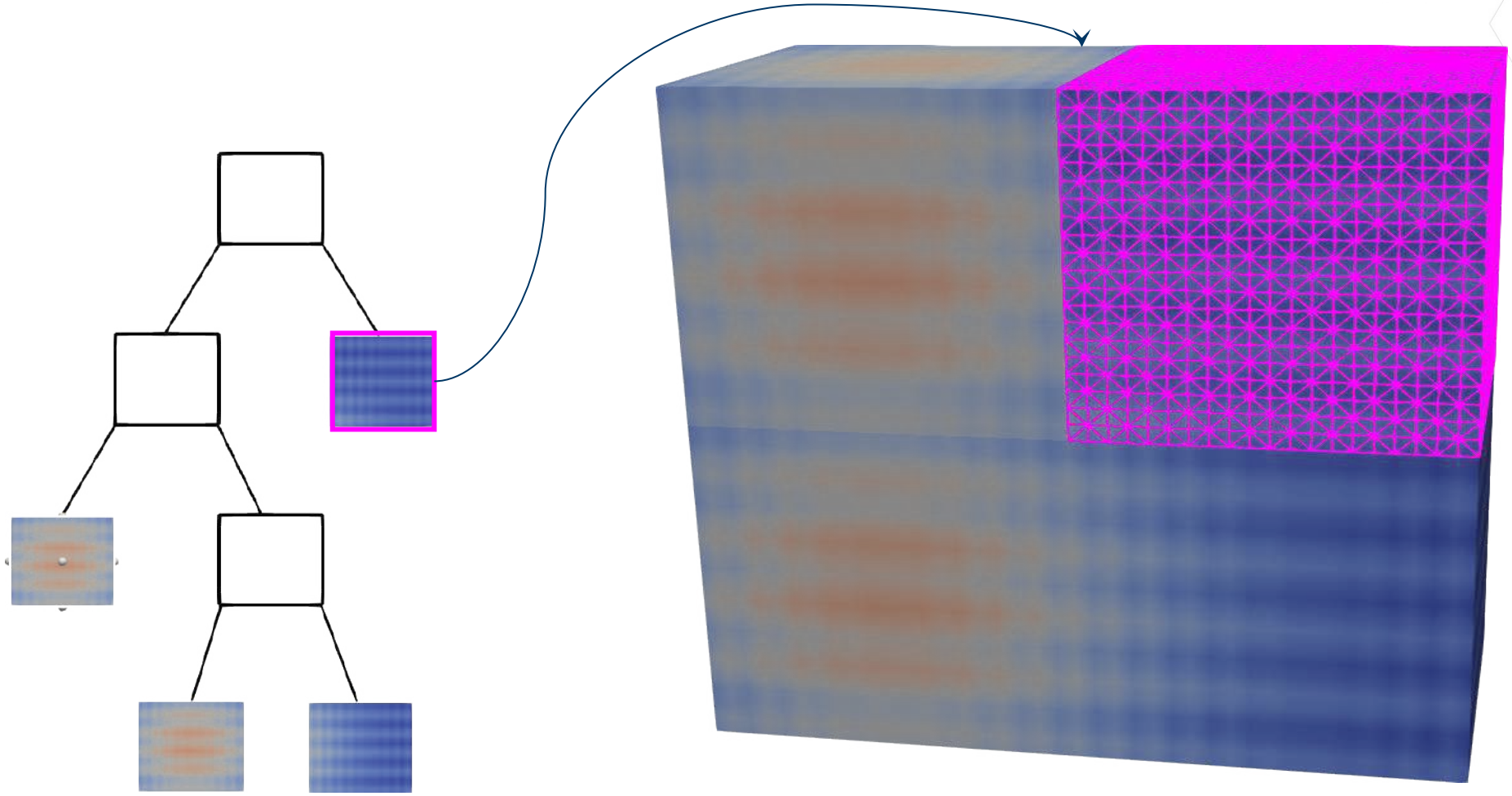
vtkMultiBlock



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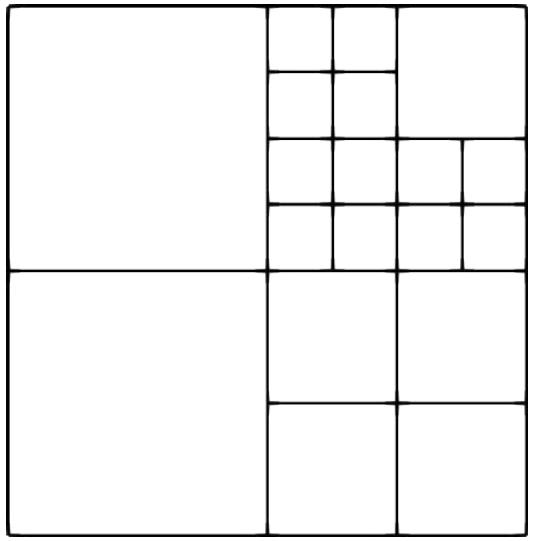
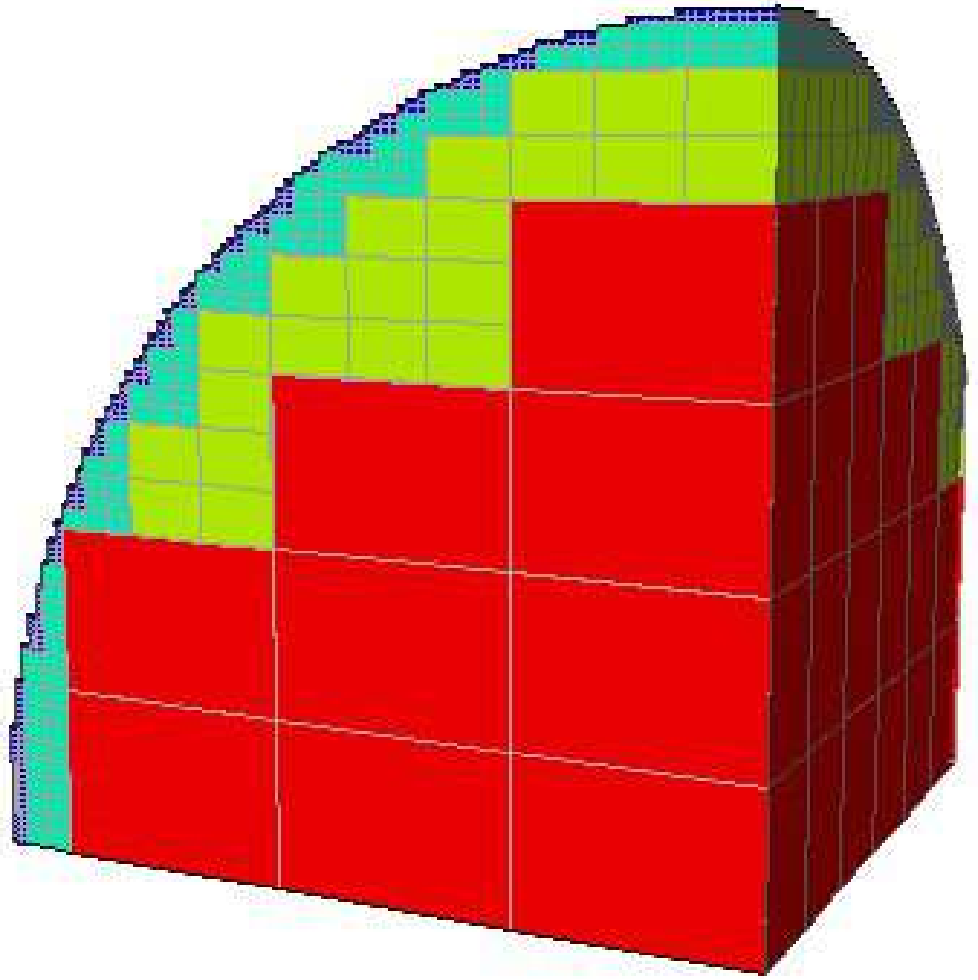
vtkHyperTreeGrid





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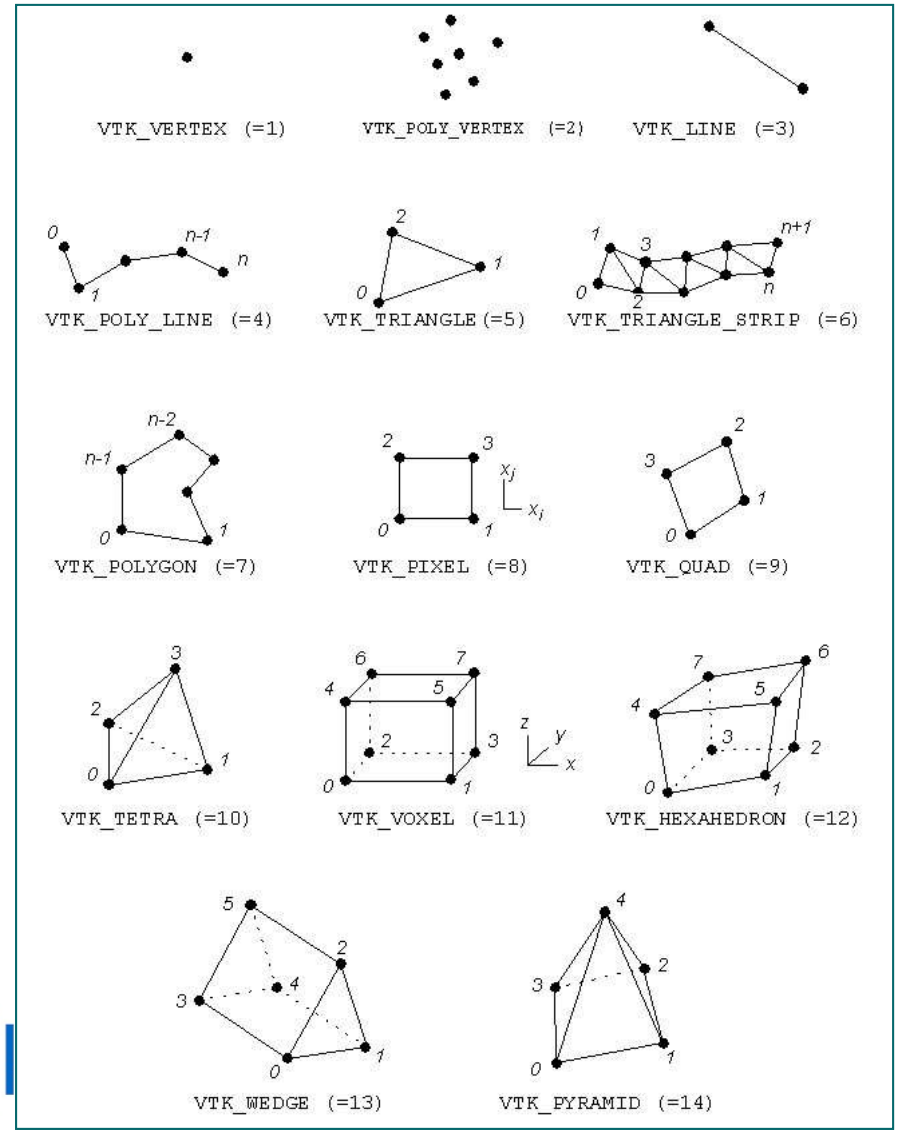
Types de cellules



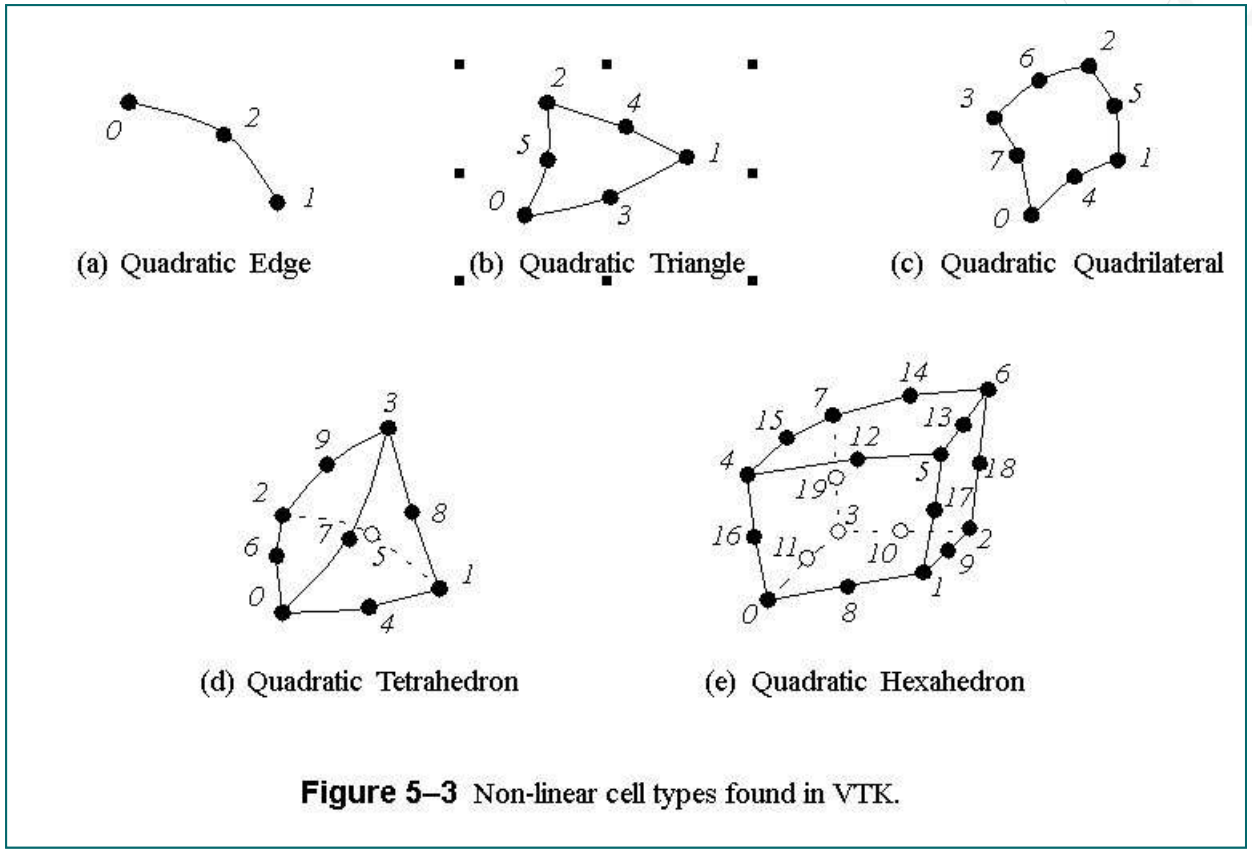
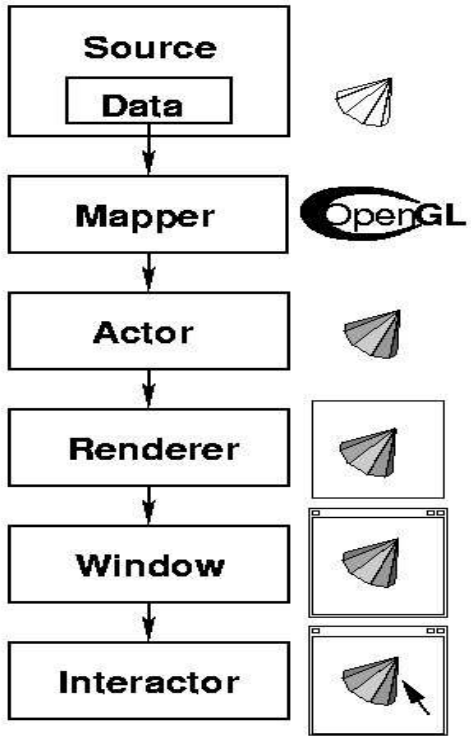
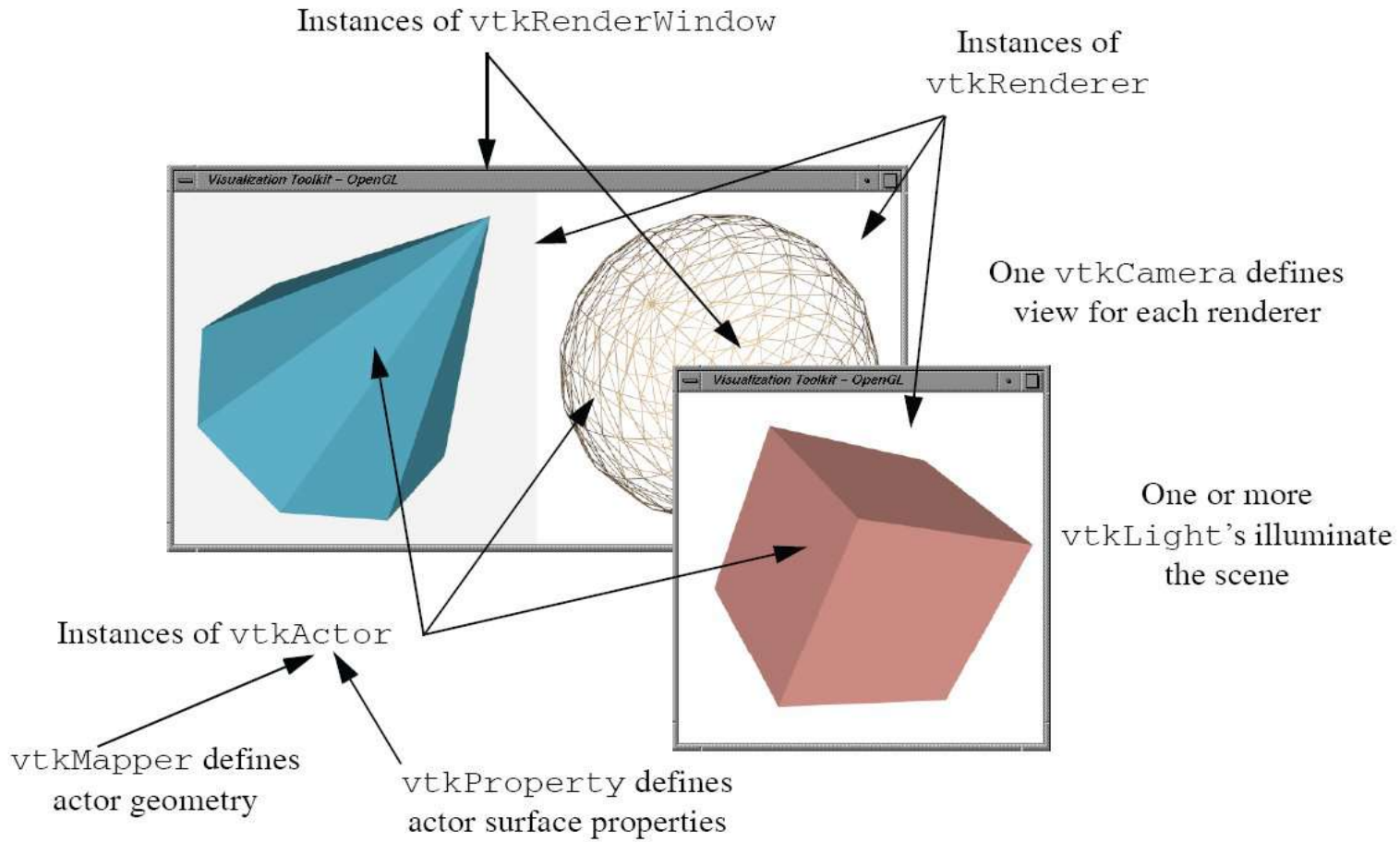


Figure 5–3 Non-linear cell types found in VTK.

Pipeline de Rendu

Rendu graphique avec VTK





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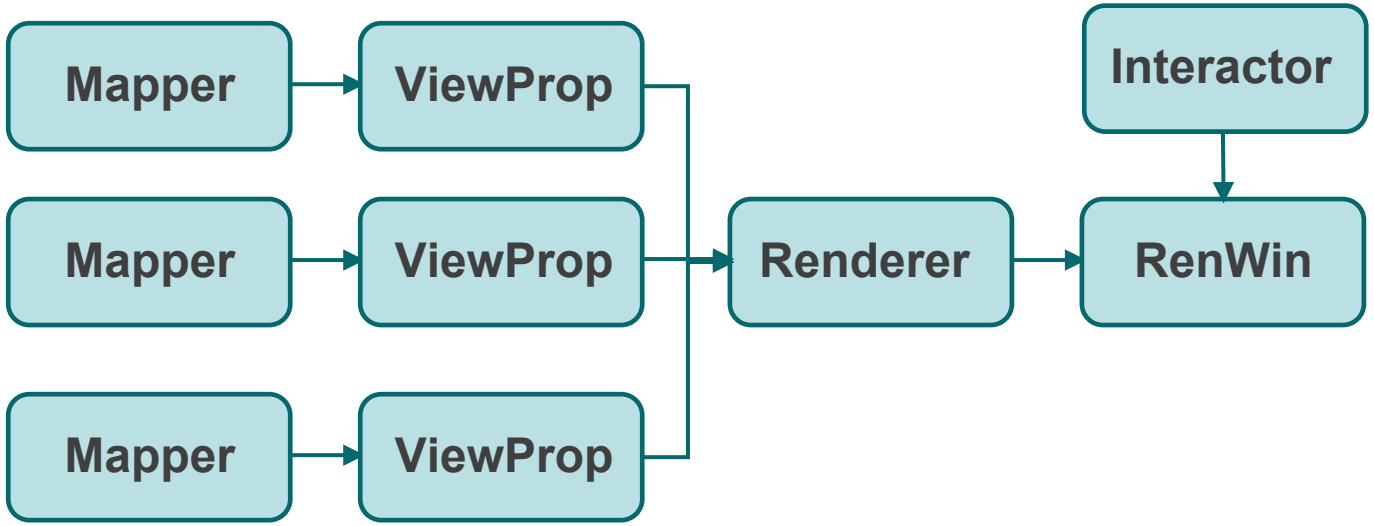
Du traitement ou pipeline de rendu

- Mapper (dernier vtkAlgorithm du pipeline de traitement)
- ViewProp (vtkActor, vtkImageActor, vtkVolume)
- Renderer (comment afficher)
- RenderWindow (où afficher)
- RenderWindowInteractor (ajout d'interaction)



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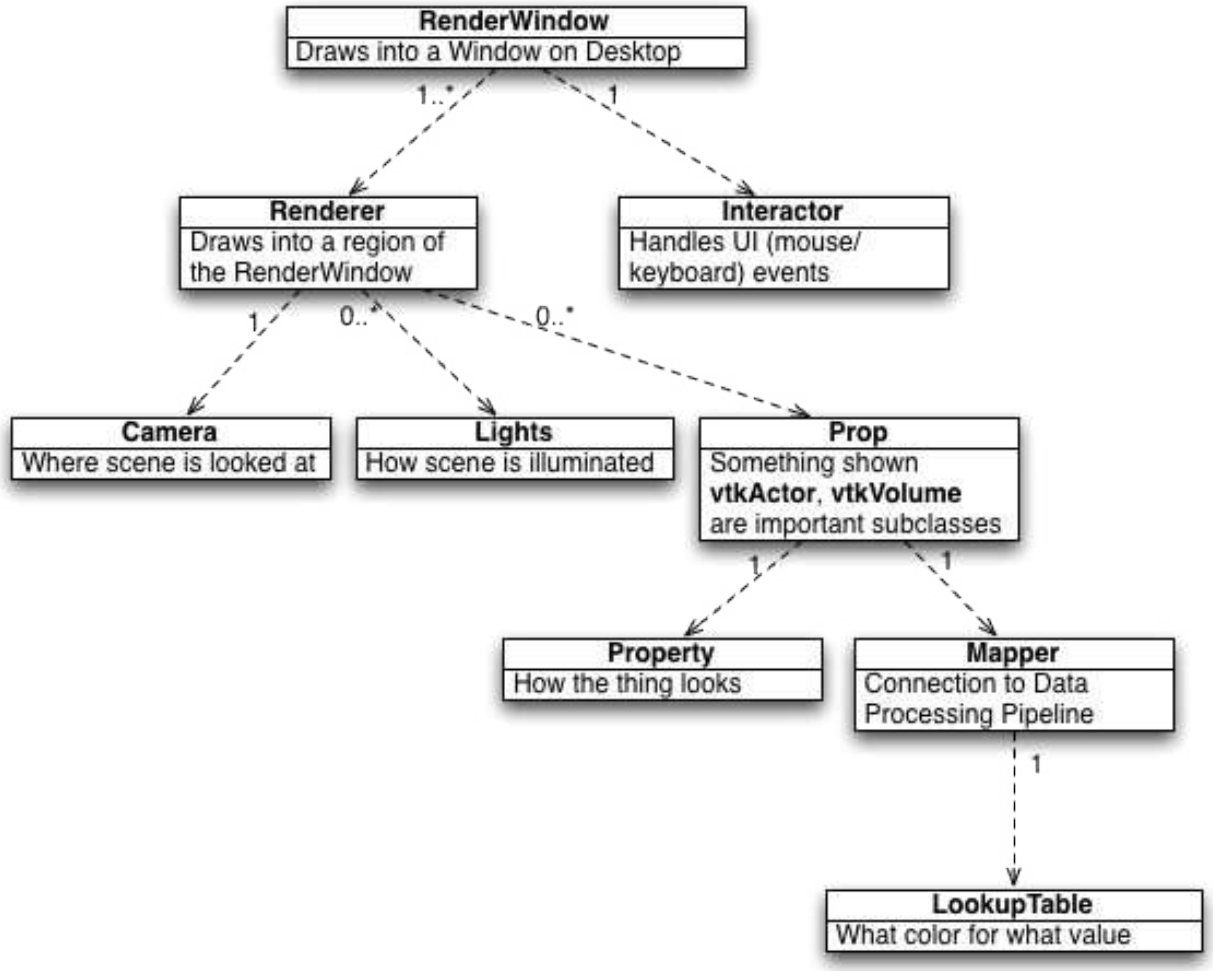
Scene VTK

- vtkRenderWindow – contient l'image finale
- vtkRenderer – dessine dans une vtkRenderWindow
- vtkActor – combine les propriétés et la géométrie
- vtkProp, vtkProp3D sont des superclasses
- vtkProperty – contient des propriétés
- vtkLights - illumine les acteurs
- vtkCamera – effectue le rendu de la scène
- vtkMapper - représente la géométrie
- vtkPolyDataMapper, vtkDataSetMapper sont des sous classes
- vtkTransform – positionne les acteurs

Moteur de rendu de VTK



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vtkRenderWindow

- **Dessine dans une fenêtre:**
  - AddRenderer() – Ajoute un vtkRender
  - SetSize() – Définie la taille de la fenêtre
  - SetPosition() – Définie la position de la fenêtre
  - StereoType, StereoRenderOn/Off – contrôle la stéréo
  - DesiredUpdateRate – utiliser pour contrôler le niveau de détail
  - DoubleBuffer –double buffering on/off
  - Render() – mets à jour le pipeline de rendu

vtkRenderer

- Dessine dans une region de la vtkRenderWindow
  - SetViewport() – specifie ou rendre dans la render window
  - AddViewProp() – ajoute un objet qui doit être rendu
  - SetBackground() – specifie la couleur du fond
  - SetActiveCamera() – specifie la camera active
  - ResetCamera() – remet la camera de telle sorte que tous les acteurs soient visibles

VTK Camera

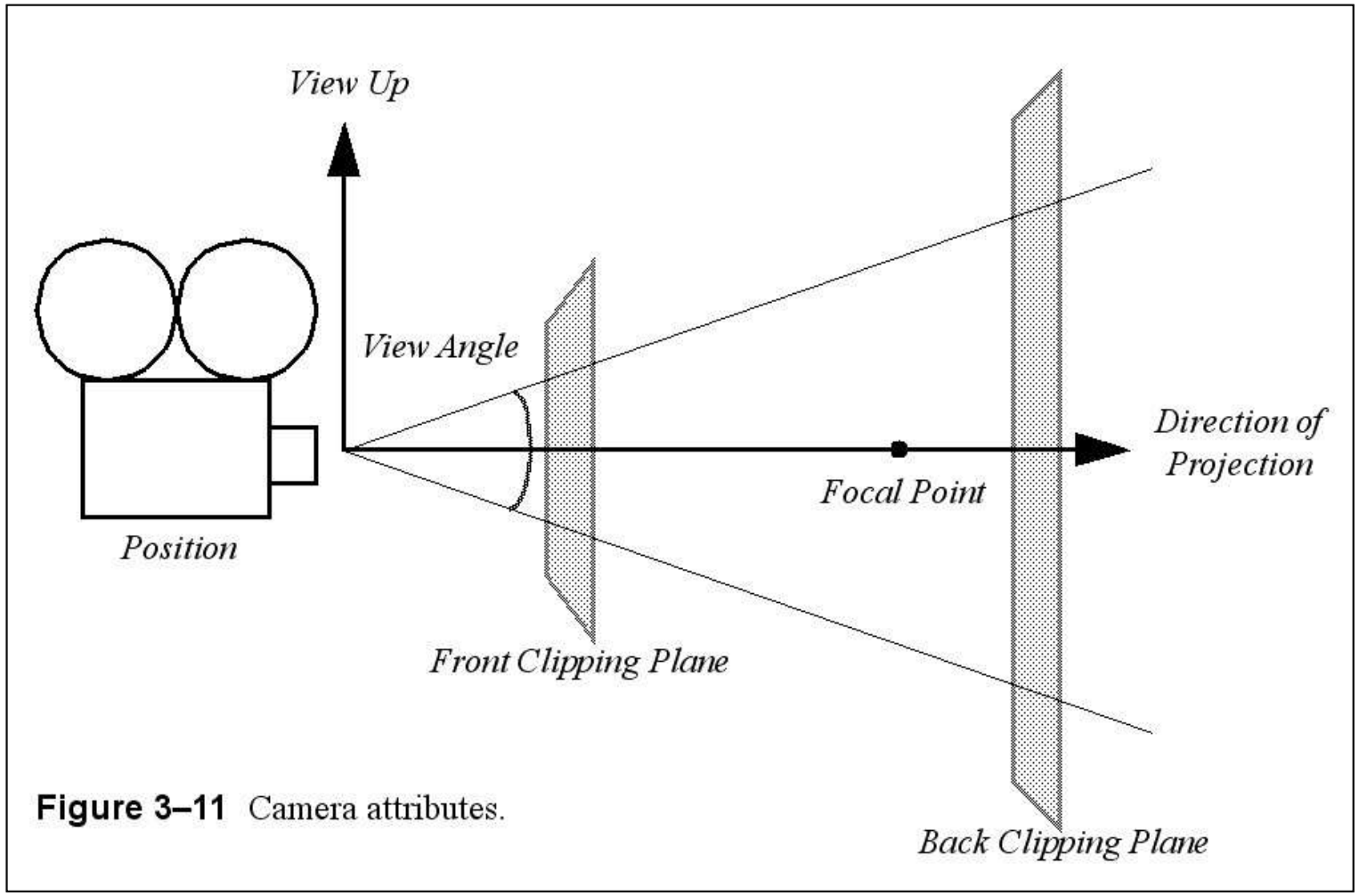

Figure 3–11 Camera attributes.

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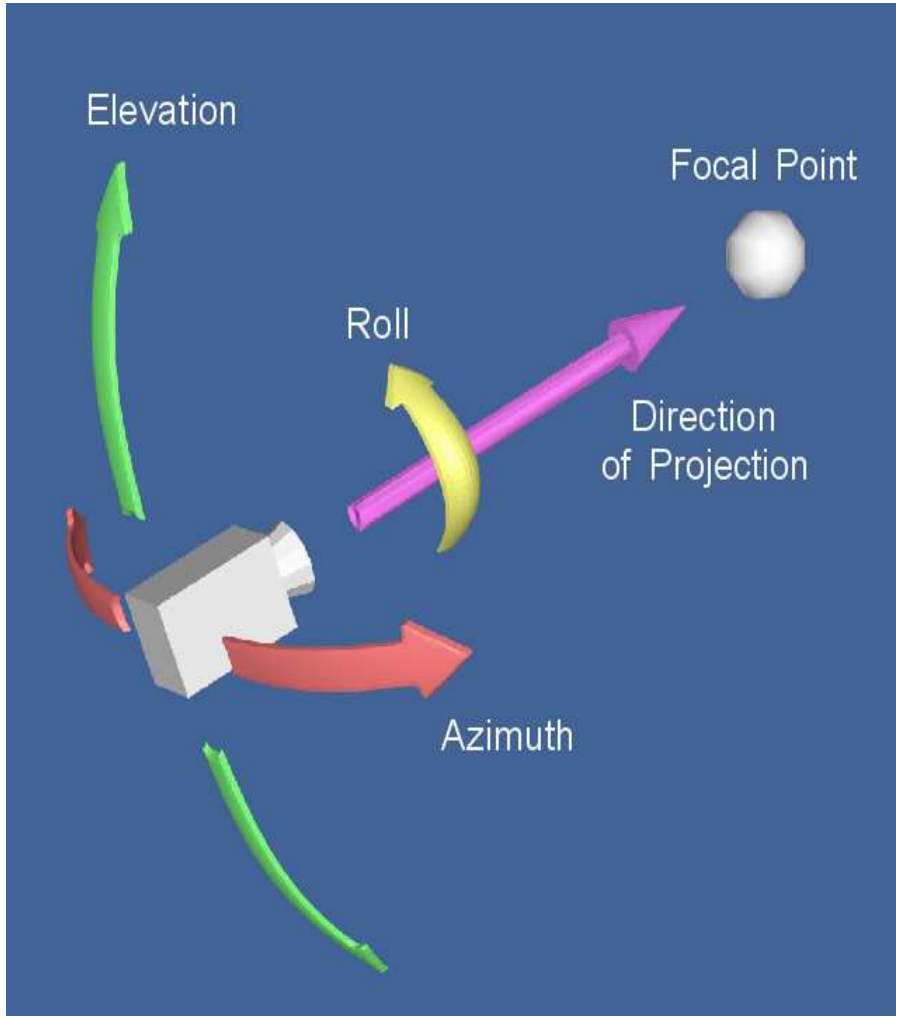
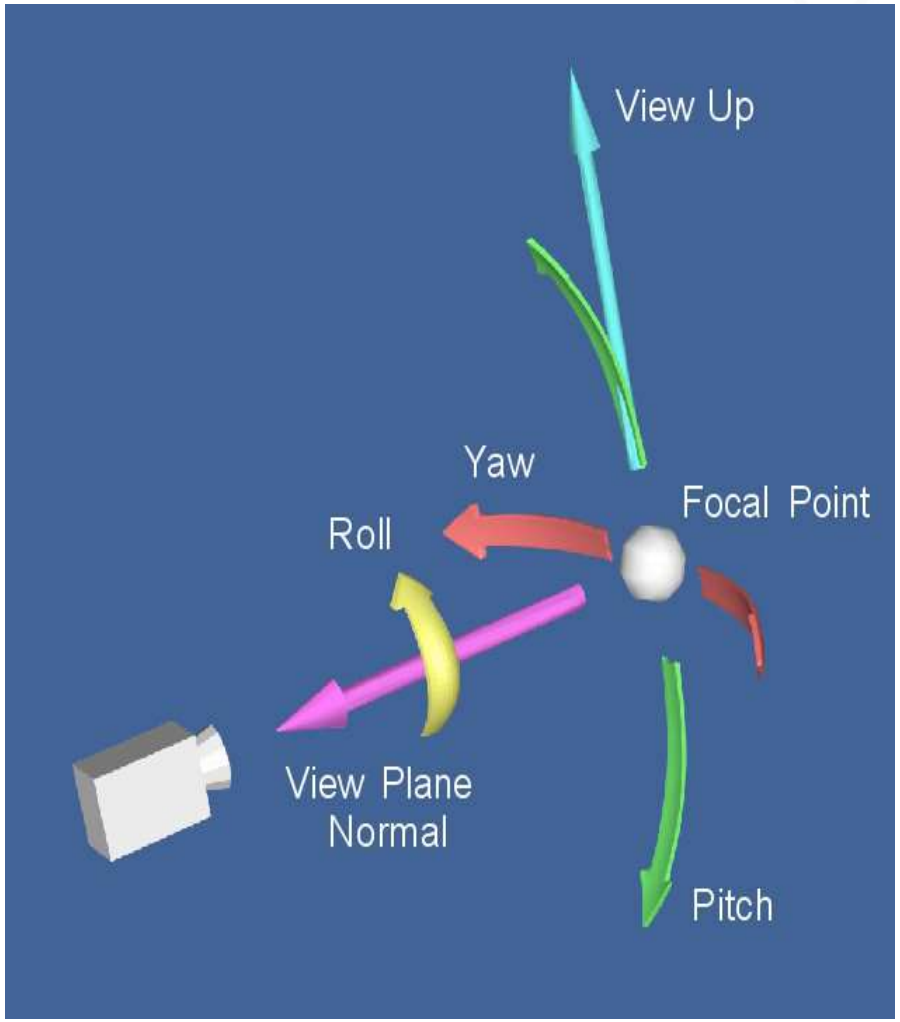
VTK Camera





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vtkLight

- **Définie comment la scène est illuminée:**
  - Color – couleur de la lumière
  - Position – position de la lumière
  - FocalPoint – ou la lumière pointe
  - Intensity – intensité de la lumiere
  - Switch – off/on
  - ConeAngle – Cone des rayons qui sorte de la lumiere

vtkActor

- Objet qui doit être rendu

- Possède potentiellement une texture
- SetOrigin()/Scale/UserTransform – Specify comment cela doit être rendu
- Position – Position dans la scene
- RotateX, RotateY, RotateZ – rotation autour d'un axe

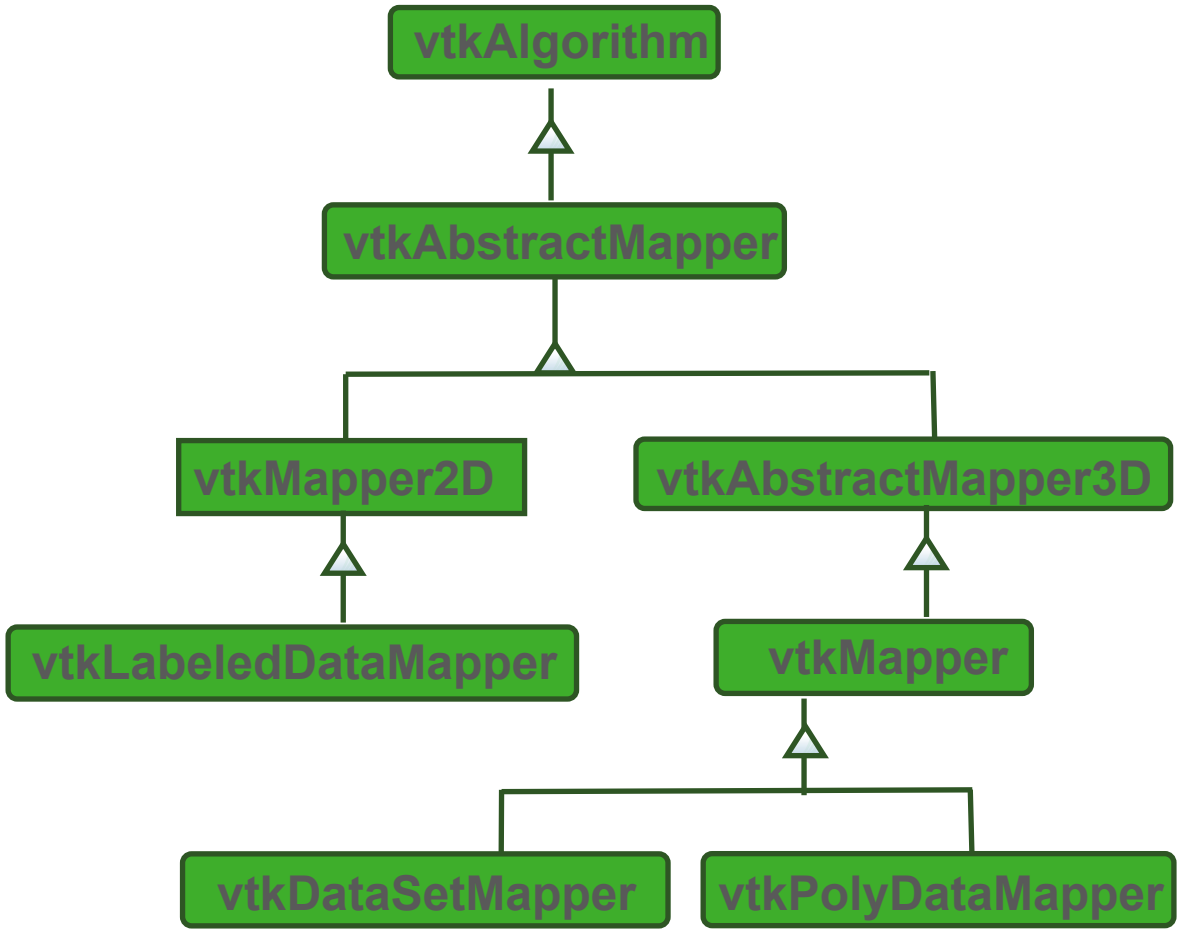
vtkProperty

- Ambient/Diffuse/SpecularColor – propriété du matériau
- Color – couleur du matériau
- Interpolation: Flat, Gouraud, PBR
- Representation: Points, Wireframe, Surface

- Opacity: contrôle la transparence

vtkMapper

- Fin du pipeline de traitement / Début du pipeline de visualisation



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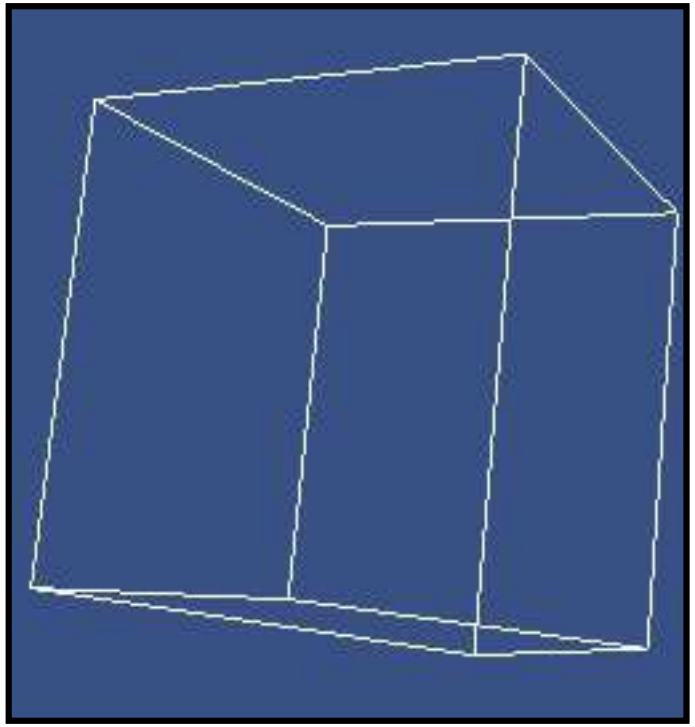
vtkProp

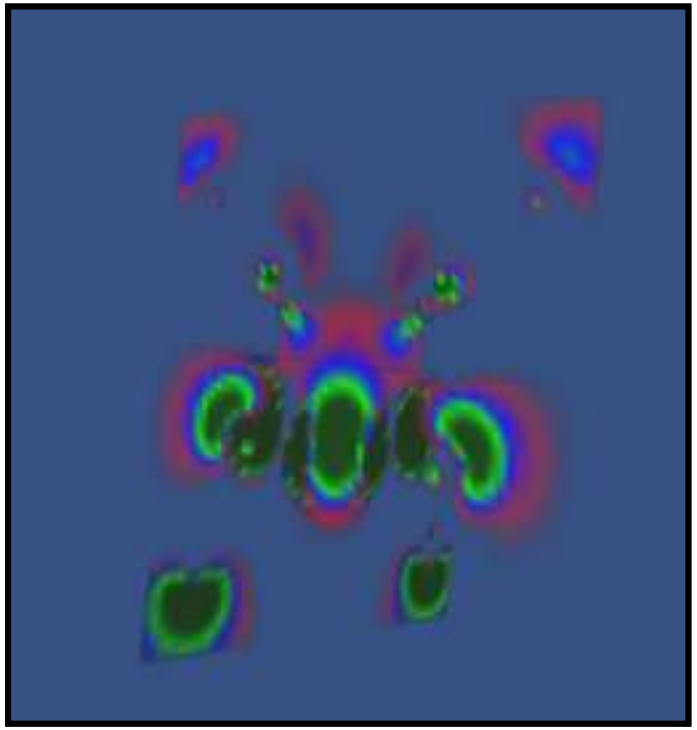
- vtkLODActor – Creation d'un acteur avec niveaux de détail
- vtkLODProp3D
- vtkFollower – toujours face à la camera
- vtkActor2D (eg. vtkTextActor)
- vtkAssembly – group of vtkProp3D
- vtkVolume – Rendu Volumique

vtkLODProp3D

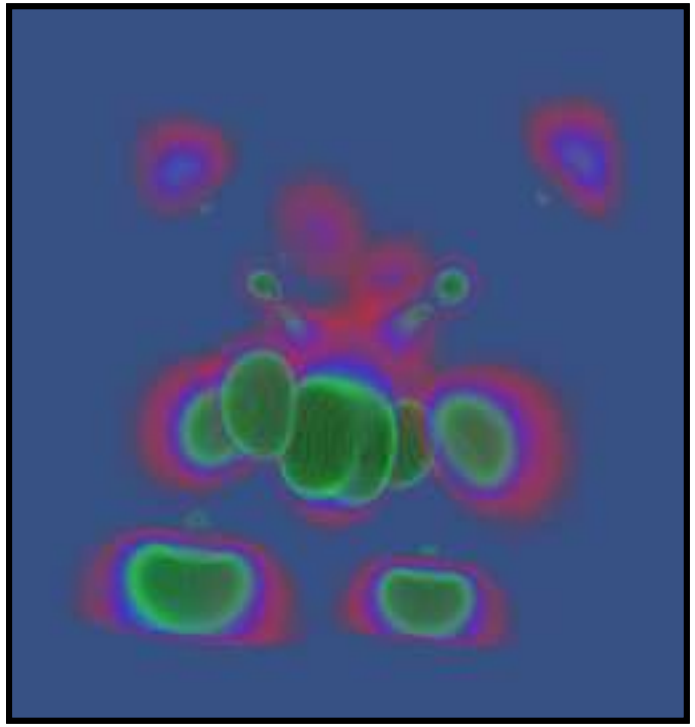
Outline



LOD 1



LOD 2



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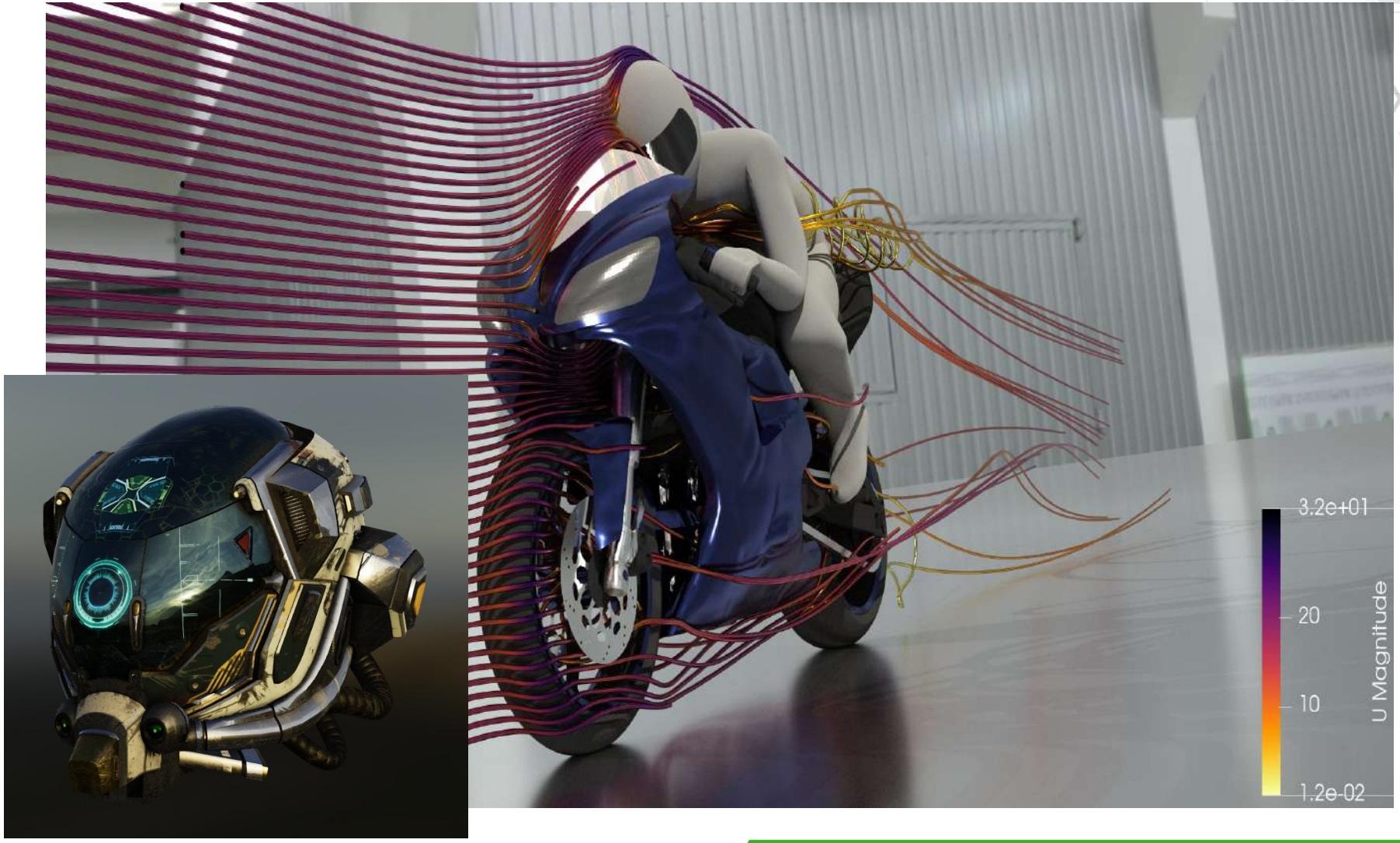
vtkAssembly

- Regroupe des acteurs entre eux
- Le résultat est similaire à un acteur

VTK – Rendu réaliste

- **OSPray:**
  - Bibliothèque CPU d'Intel
- **Physically Based Rendering (PBR)**
  - GPU



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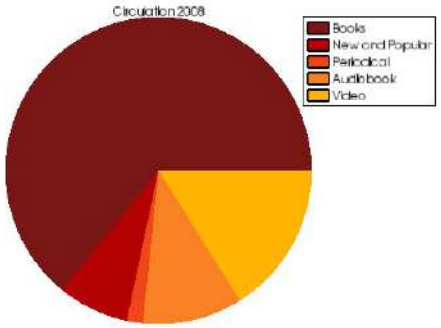
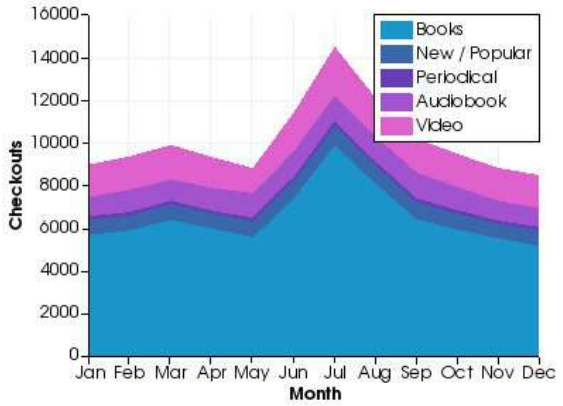
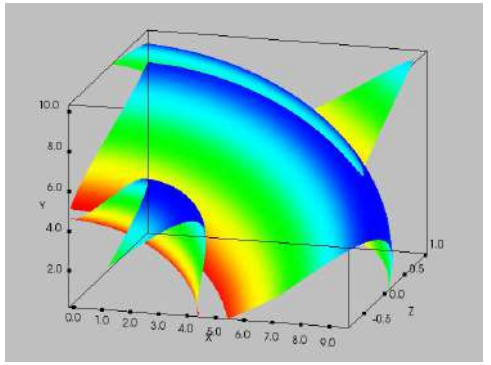
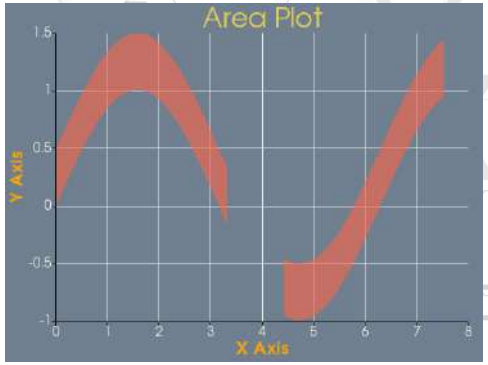
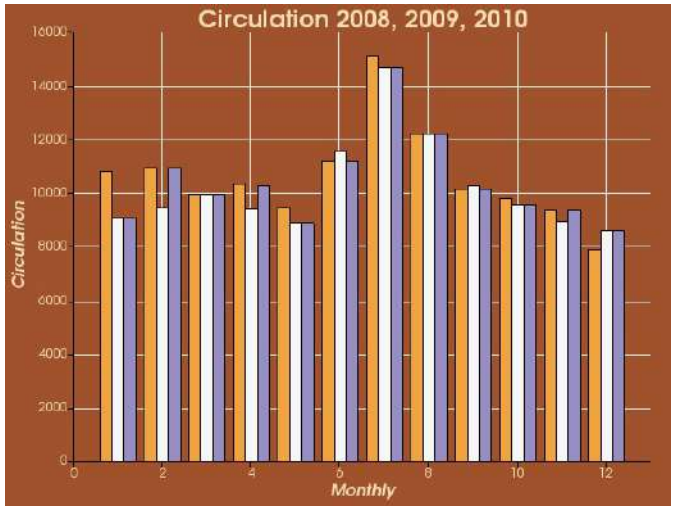
VTK 2D

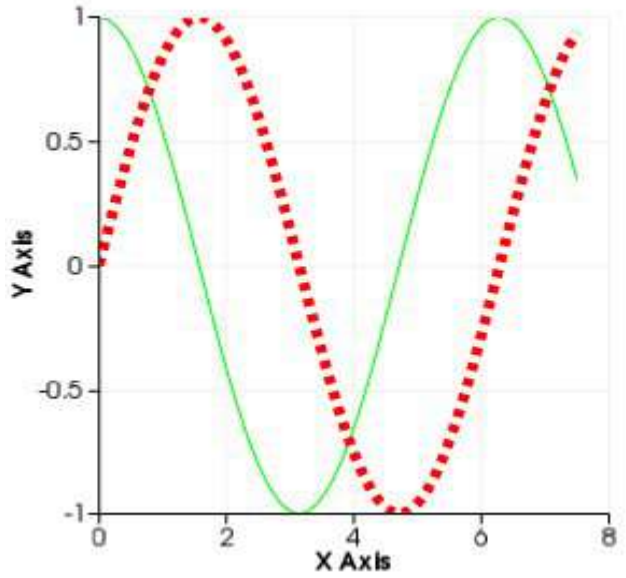


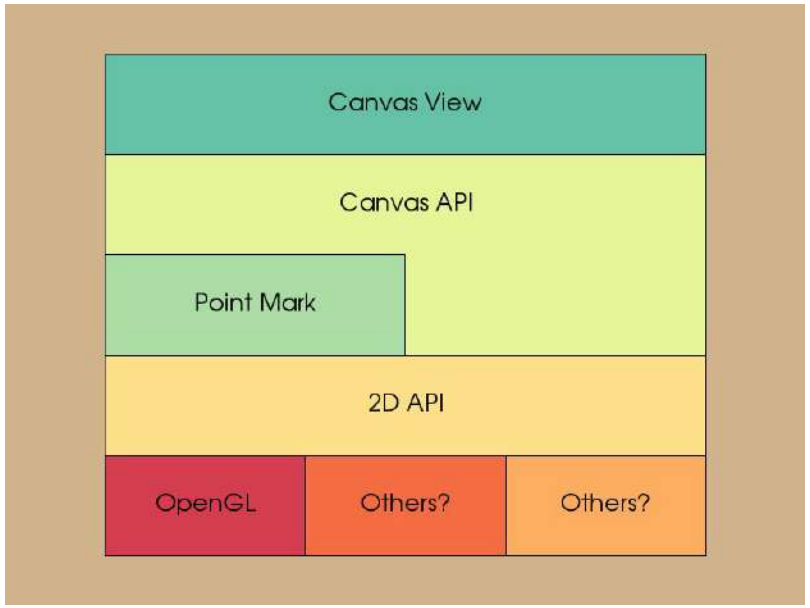












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Pipeline de Traitement

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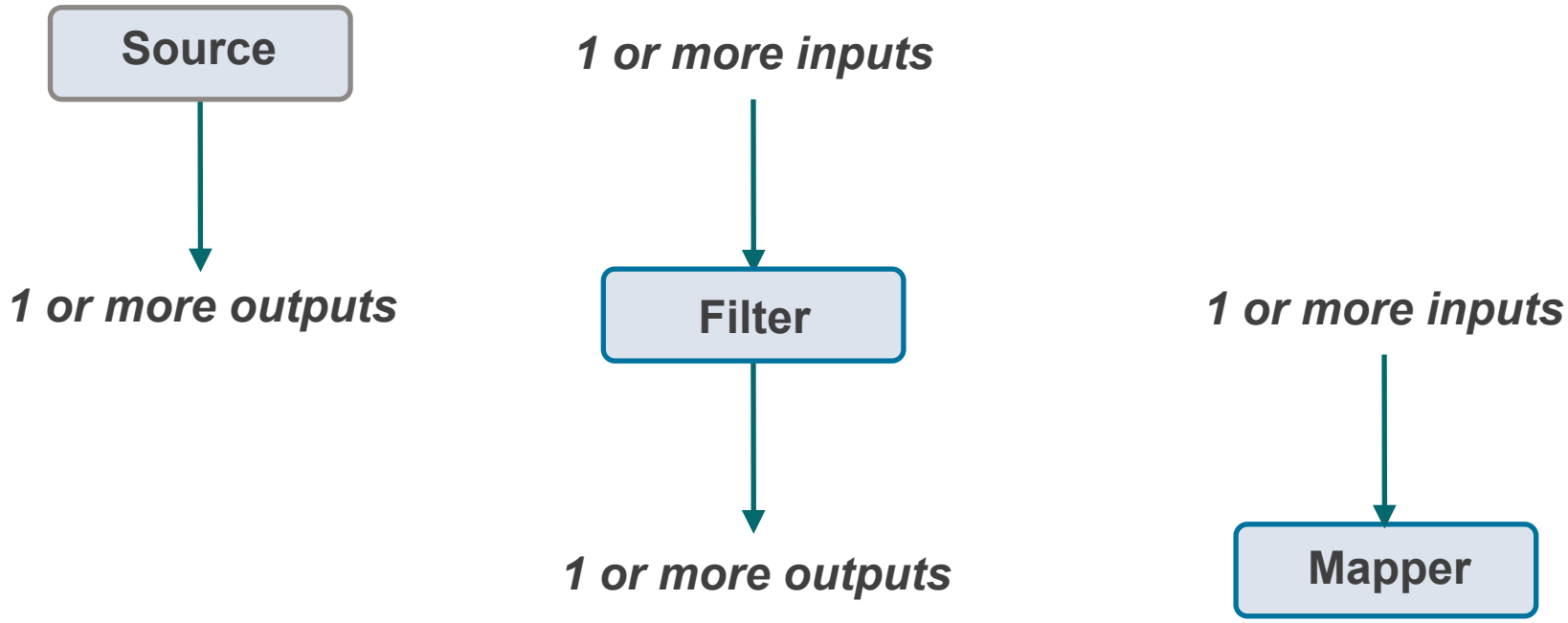
Algorithmes

- Les algorithmes (vtkAlgorithm) opèrent sur des données



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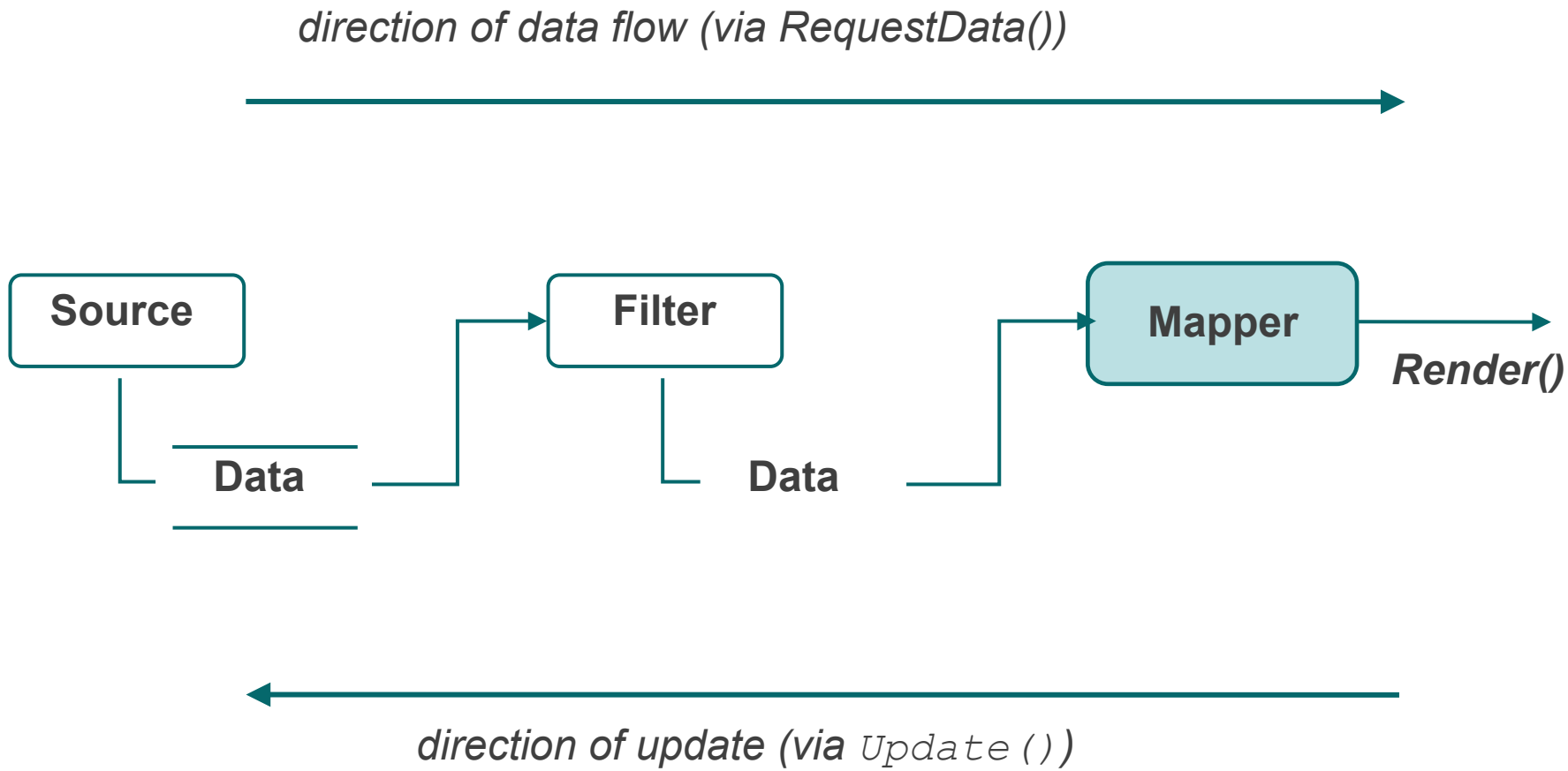
Exemples d'Algorithmes

- **Readers: parse files and produce VTK data structures**
  - vtkDataSetReader, vtkPNGReader, vtkPLOT3DReader, vtkParticleReader, vtkExodusReader, vtkOpenFOAMReader
- **Contour: extract isocontours within data**
  - vtkContourFilter
- **Probing: sample attributes at set of locations**
  - vtkProbeFilter
- **Warping: bend geometry by value**
  - vtkWarpScalar, vtkWarpVector
- **Glyph: place and orient markers within data**
  - vtkGlyph2D, vtkGlyph3D
- **Streamline: advect along data to display or compute flow characteristics**
  - vtkStreamline

Execution du Pipeline



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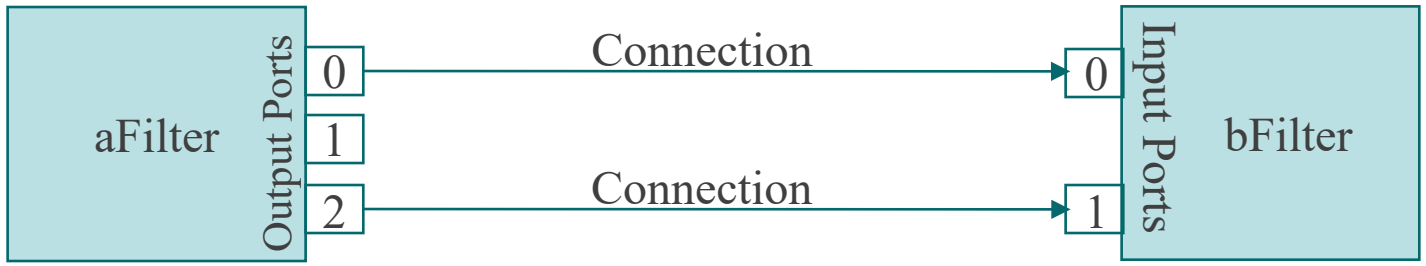
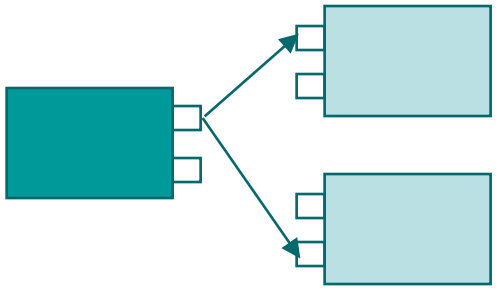
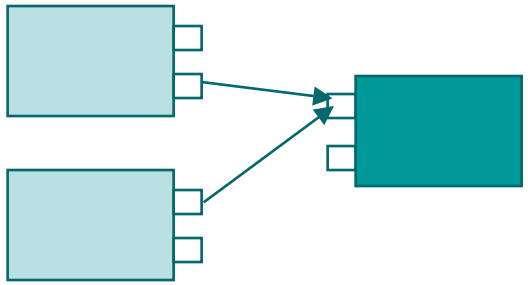
Topologie du pipeline





Reuse an output port: OK



Several connections on an input port: `AddInputConnection()` if allowed by the filter (ex: vtkAppendFilter)

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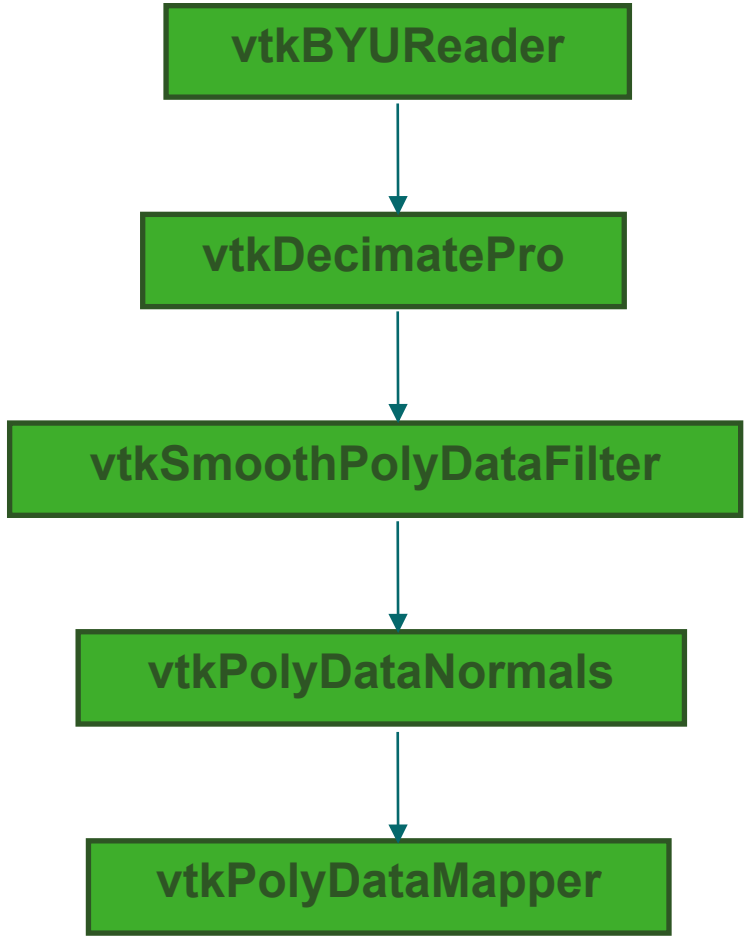
Exemple de Pipeline



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Exemple de Pipeline

```
vtkNew<vtkBYUReader> byu;
  byu->SetGeometryFileName("fran_cut.g”);

vtkNew<vtkDecimatePro> deci;
  deci->SetInputConnection(byu->GetOutputPort());
  deci->SetTargetReduction(0.9);
  deci->PreserveTopologyOn();
  deci->SetMaximumError(0.0002);
```

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Exemple de Pipeline

```
vtkNew<vtkSmoothPolyDataFilter> smooth;
  smooth->SetInputConnection(deci->GetOutputPort());
  smooth->SetNumberOfIterations(20);
  smooth->SetRelaxationFactor(0.05);

vtkNew<vtkPolyDataNormals> normals;
  normals->SetInputConnection(smooth->GetOutputPort());

vtkNew<vtkPolyDataMapper> cyberMapper;
  cyberMapper->SetInputConnection(normals->GetOutputPort());

vtkNew<vtkActor> cyberActor;
  cyberActor->SetMapper(cyberMapper);
  cyberActor->GetProperty()->SetColor(1.0, 0.49, 0.25);
  cyberActor->GetProperty()->SetRepresentationToWireframe();
```

Exemple de Pipeline

```
vtkNew<vtkRenderer> ren1;
  ren1->AddViewProp(cyberActor);
  ren1->SetBackground(1, 1, 1);

vtkNew<vtkRenderWindow> renWin;
  renWin->AddRenderer(ren1);
  renWin->SetSize(500, 500);

vtkNew<vtkRenderWindowInteractor> iren;
  iren->SetRenderWindow( renWin );
  iren->Start();
```

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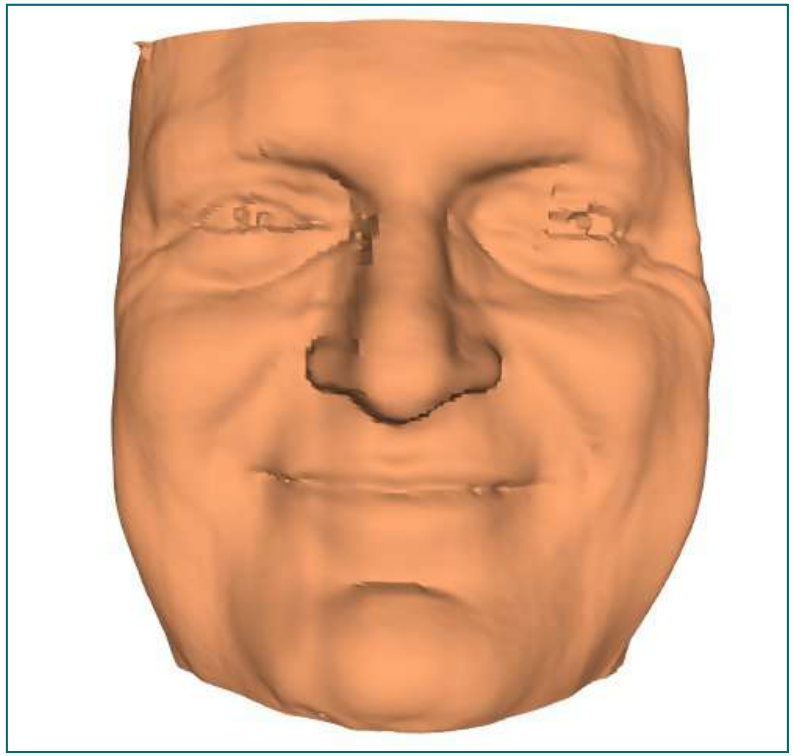
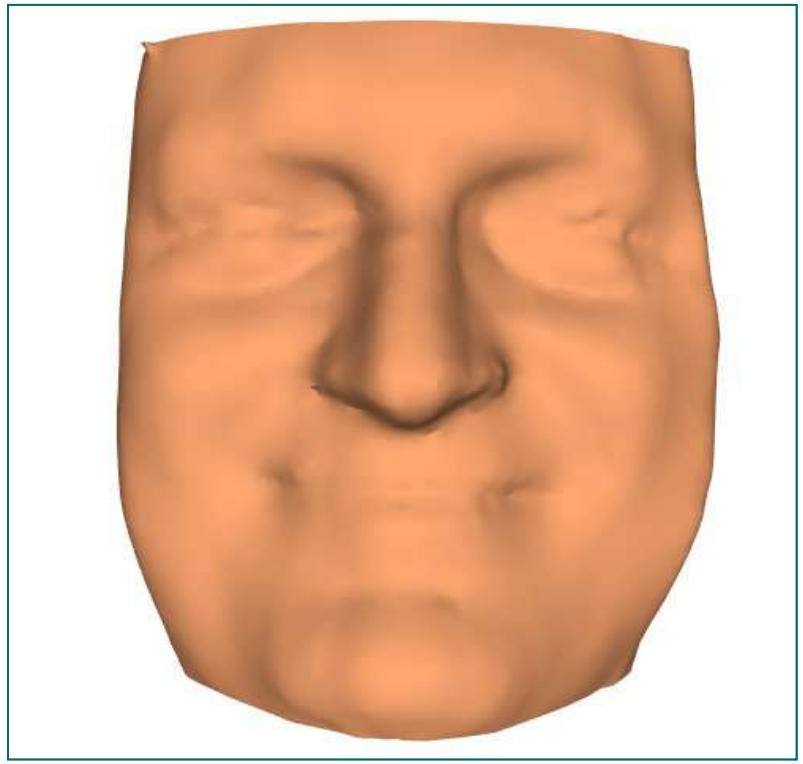
Resultat



Before
(52,260 triangles)



After Decimation
and Smoothing
(7,477 triangles)

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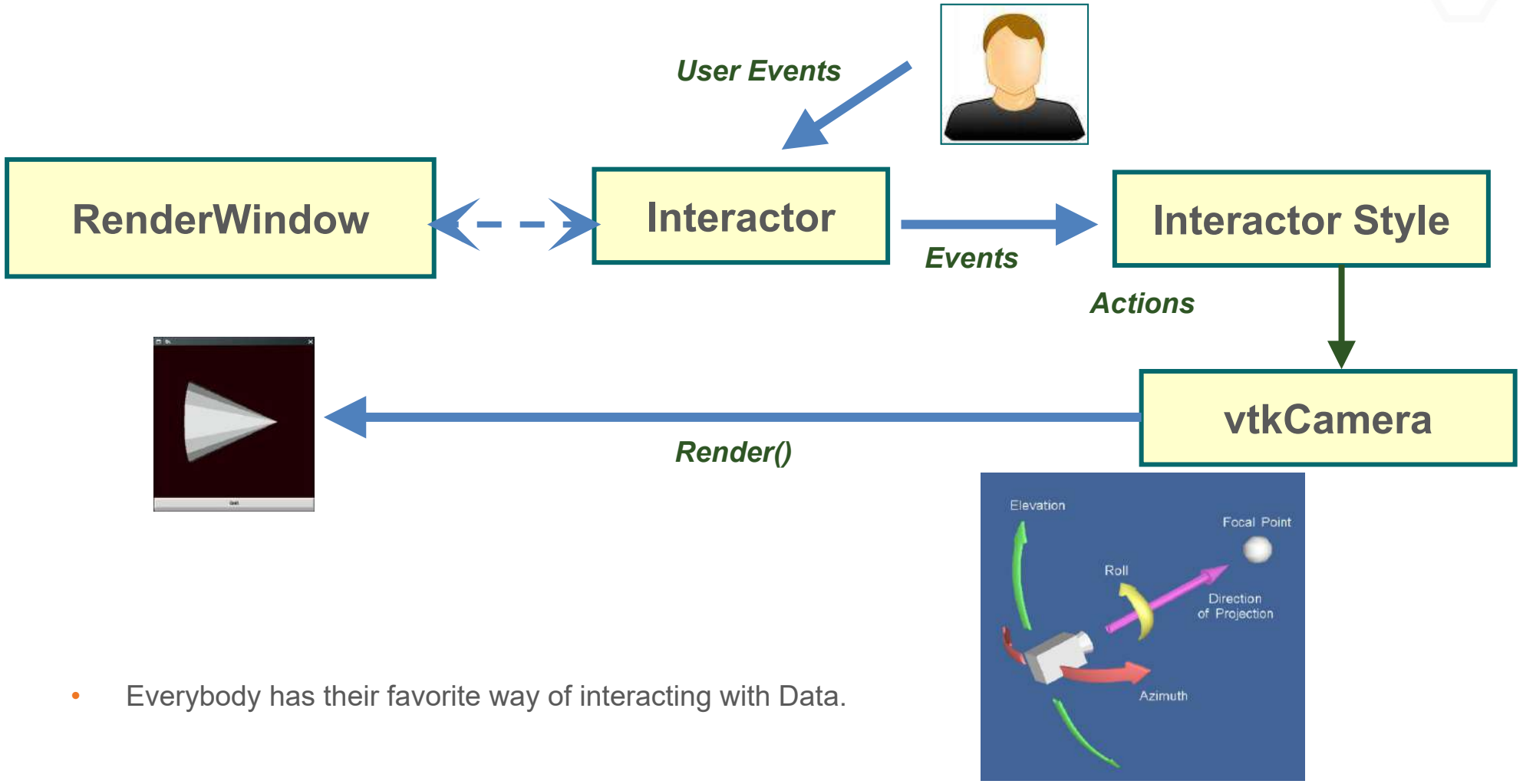
Interaction et Widgets



- Everybody has their favorite way of interacting with Data.

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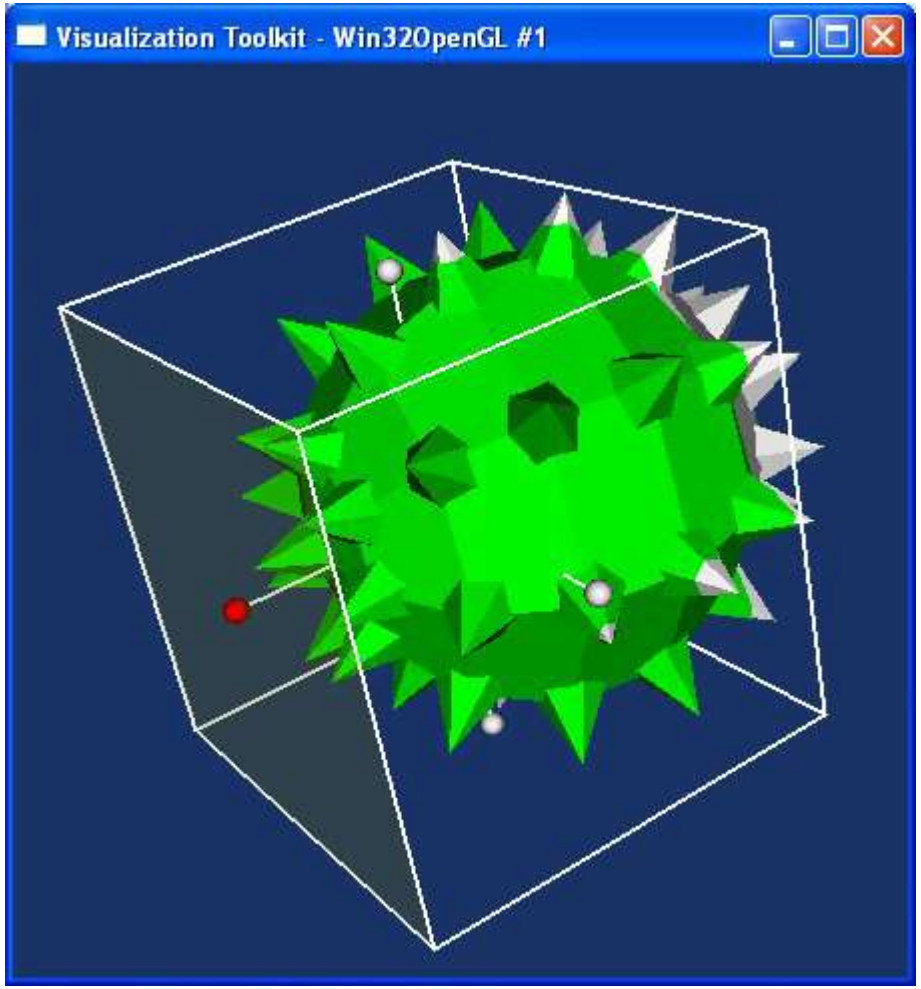
vtkBoxWidget



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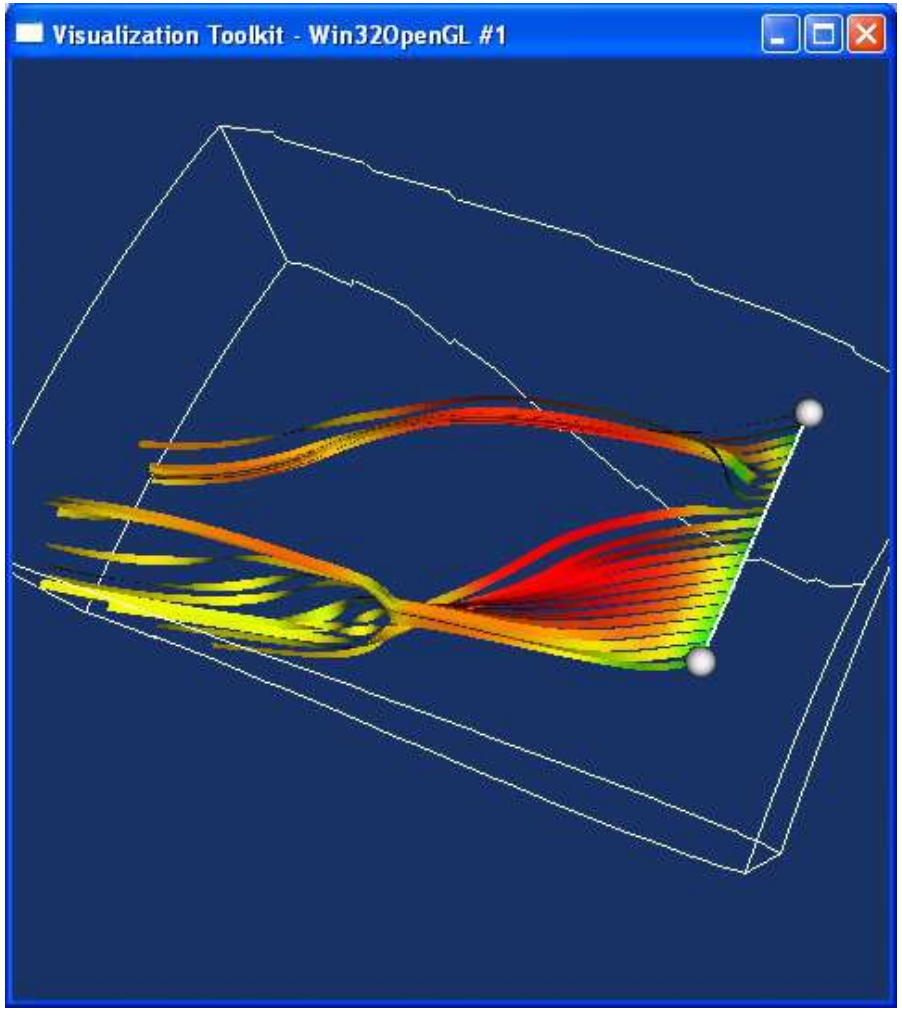
vtkLineWidget



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TP

- En Python
- Pipeline de visualisation
- Lien avec ITK