INTRODUCTION TO VTK

Gustav Taxén, Ph. D.
Associate Professor
School of Computing Science and Communication
Royal Institute of Technology, Stockholm
gustavt@csc.kth.se

OVERVIEW

Programming library

Development of scivis apps

Very powerful

1133 C++ classes (v 5.0)

C++, Tcl/Tk, Python, and Java bindings

OVERVIEW

Over-designed

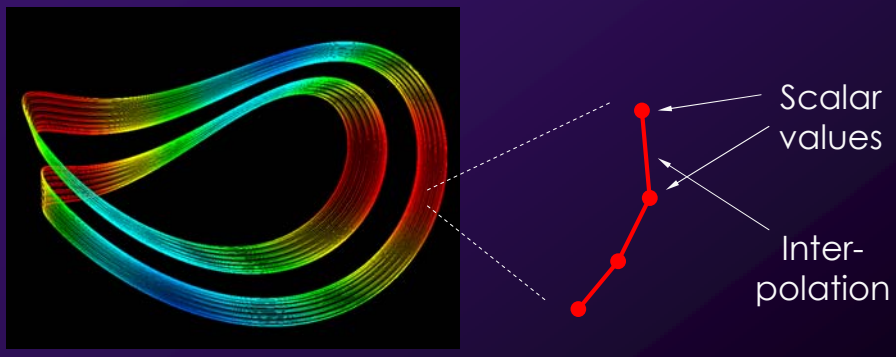
Very complex

Limited on-line tutorial material

Undergone semantic/syntactic changes

Very steep learning curve!

WHAT IS VISUALIZED?



DEFINITIONS

Point ≡ Location in 3D space

Attribute data ≅ Information stored at points
Book is vague
Called **point data** in the code

DEFINITIONS

Dataset = Structure + Attribute data

Geometry
(the points)

Topology
(how points
are connected)

DEFINITIONS

A topology is built up from **cells**

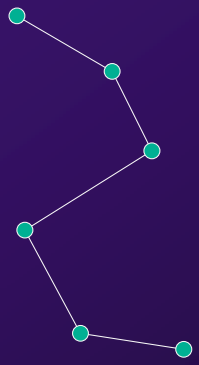
There are different kinds of cells

There are different kinds of datasets in VTK that organize cells in different ways

Some datasets use only one or a couple of cell types

Other are more general

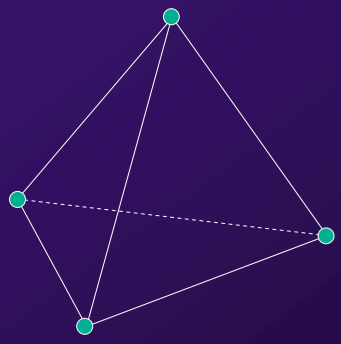
CELL EXAMPLES



This is a **polyline** cell

It consists of 2 or more connected lines

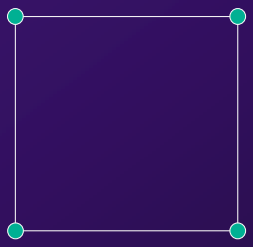
CELL EXAMPLES



This is a **tetrahedron** cell

It consists of 3 triangles

CELL EXAMPLES



This is a **pixel** cell

It consists of one quad, aligned with one of the world coord system planes

CELLS

There are 16 kinds of **linear** cells in VTK

They interpolate attribute data linearly between points

There are **non-linear** cells too

They interpolate using polynomal basis functions

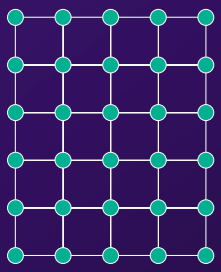
DATA SETS

Dataset = Structure + Attribute data

Some datasets impose a cell structure

Others are more general

DATASETS



This is an **Image** dataset

This example uses pixel cells

There are 5x6 = 30 points and 4x5 = 20 cells

The image dataset can use line, pixel, or voxel cells

DATASETS

The **PolyData** dataset consists of:

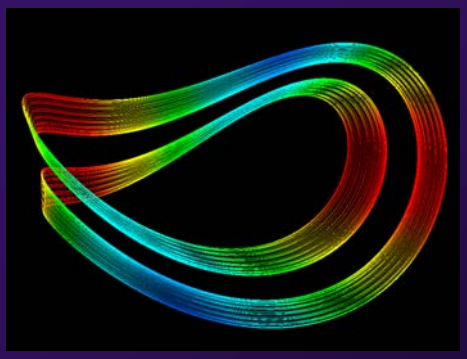
a set of vertex cells
a set of line cells
a set of polygon cells
a set of triangle strip cells

It is used for unstructured data

CELL ARRAYS

For datasets where lists of cells are involved (e.g., PolyData) you specify the cells using **CellArray**:s

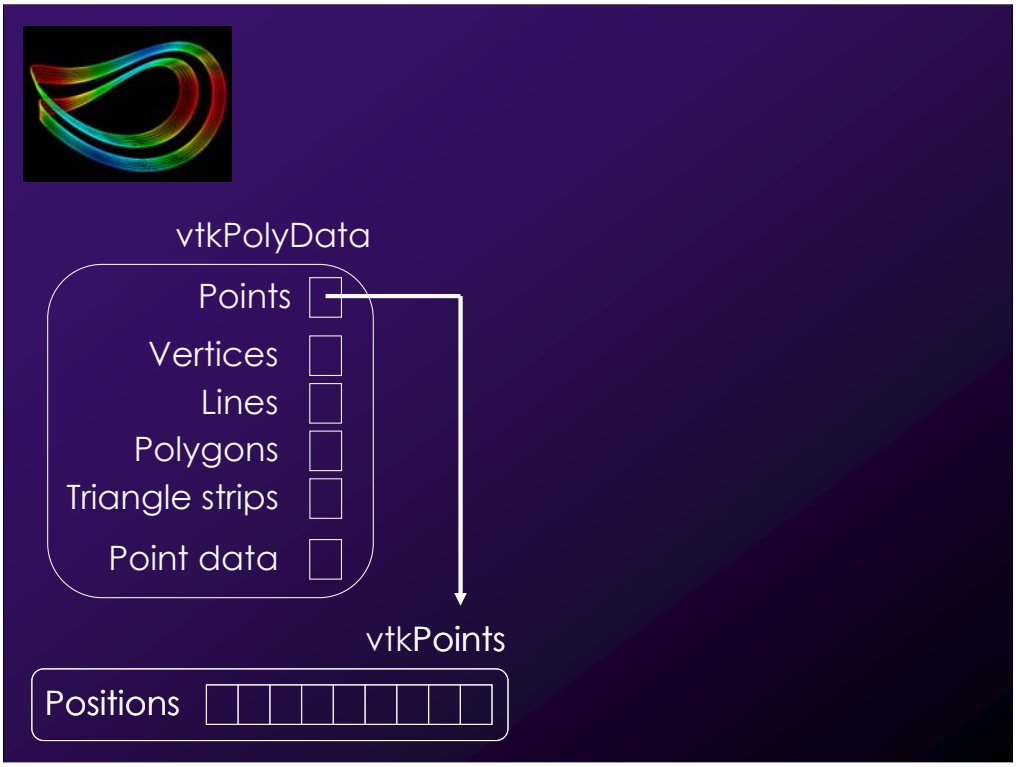
EXAMPLE



Let's see how the data in this image is organized!

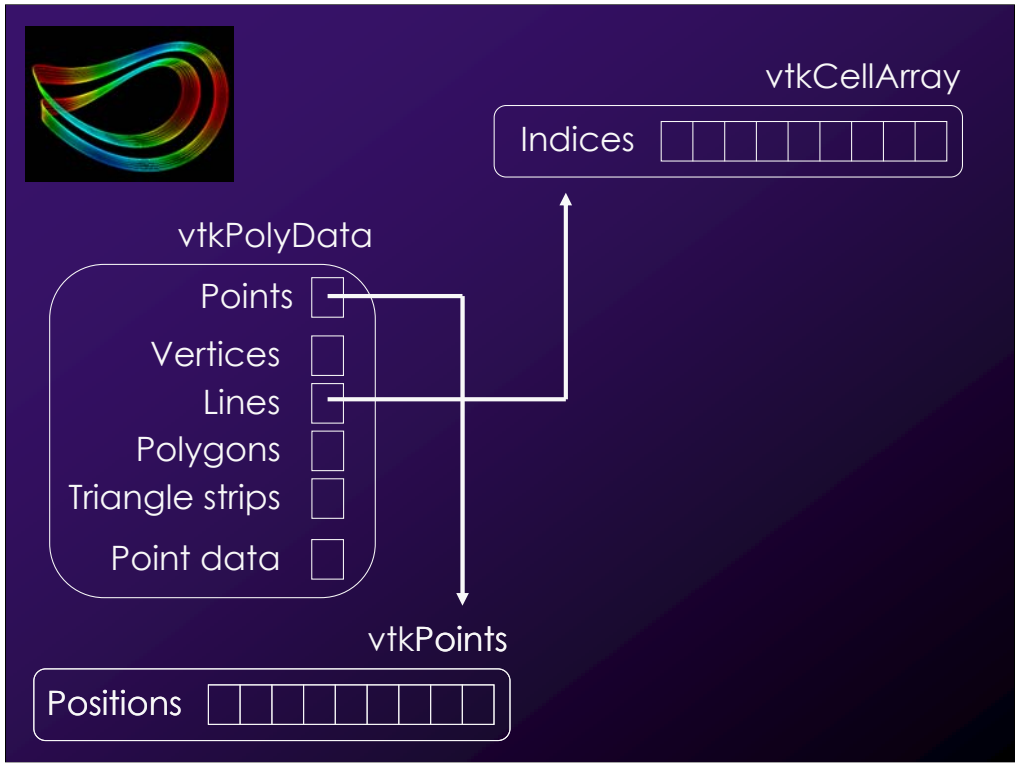
The data describes a particle trajectory

It is a line strip containing 9999 (colored) vertices



We use a PolyData dataset.

The **geometry** of the dataset are the locations of the vertices. They are specified as VTK points. A point always has 3 dimensions (x, y, z).



Since this DataSet doesn't impose a cell structure, we need to specifiy the **topology** explicitly, i.e., the cells of the dataset, i.e., what the relationship between the points is.

THIS IMAGE IS VERY IMPORTANT – EVERYONE SHOULD UNDERSTAND IT BEFORE MOVING ON!

A PolyData dataset can connect points in different ways. It can contain vertices, lines, polygons, and/or triangle strips.

Since PolyData is an unstructured dataset, we need to specify cells explicitly. It must be done via CellArrays.

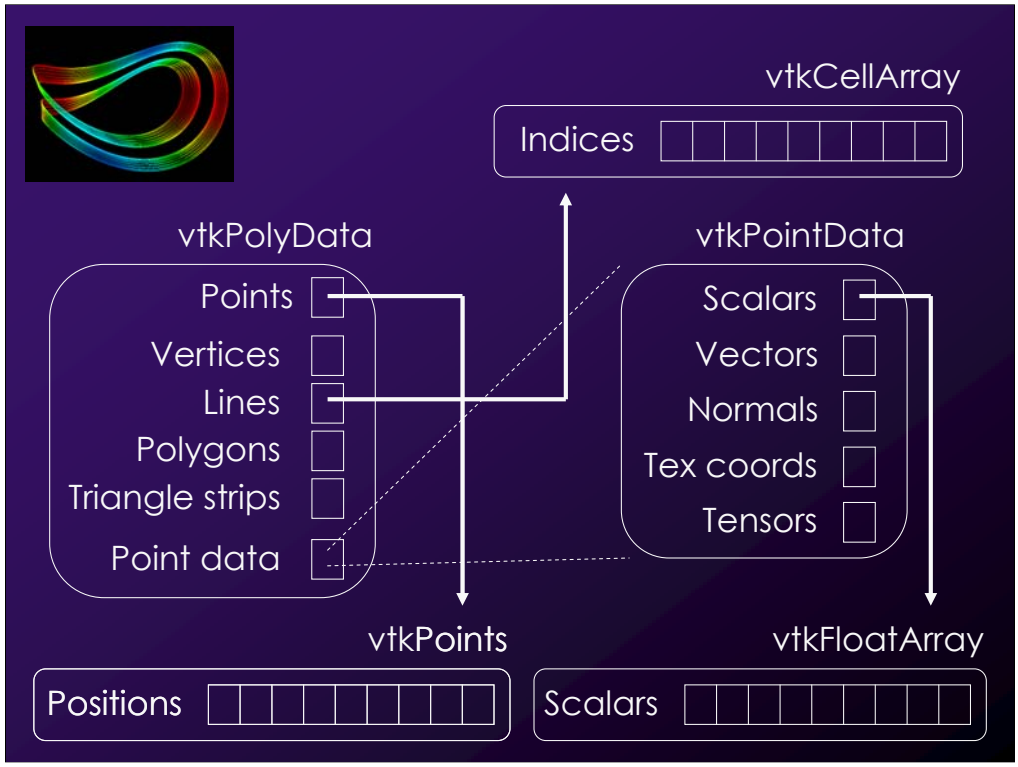
There is one CellArray for the vertices, one for the lines, one for the polygons, and one for the tristrips.

A CellArray is an integer-valued array containing point list indices. Together, these indices specify one or more cells. How the indices are combined into cells are determined by whether we assign the CellArray as the vertices, the lines, the polygons, or the trianglestrips of the dataset.

The format of the CellArray is as follows: The first value is the number of indices for the first cell. Then follows the indices themselves. The next value is the number of indices for the second cell. Then follows the indices for the second cell, and so on.

In our case, we choose to use ONE cell. This cell will contain 9999 indices - one for each point. If a line contains more than two indices it is automatically interpreted as a line strip.

Since the data points are in order, the indices first index is 0, the second is 1, and so on up to 9998.



The next step is to assign the scalar values to the points.

The dataset contains ”attribute data”, which is VTK speak for ”values defined at point locations”. These values are the ones that are interpolated by VTK when we generate the image.

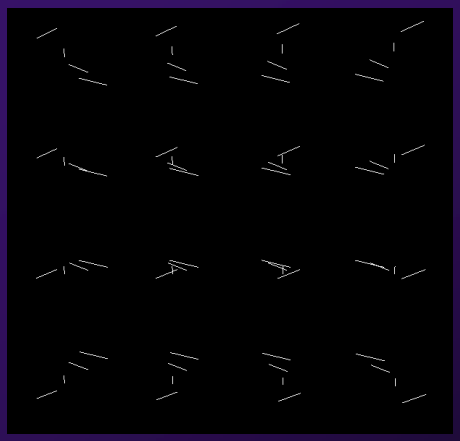
In the API, the ”attribute data” is denoted as ”point data”. At each point, we can store a scalar, a 3D vector, a normal, a 2D tex coord, or a tensor. I’m not sure whether it’s OK to store more than one of these at each point.

Here, we want to store scalars, which means that we need one floating-point value for each geometry point. This has been provided to us in the same data file that contains the particle trajectory data.

”Attribute data” (or ”Point data”) is stored in FloatArrays. If the data is multidimensional, it is interleaved in the array. For example, a 3D vector at each point would be stored as X0 Y0 Z0 X1 Y1 Z1, and so on.

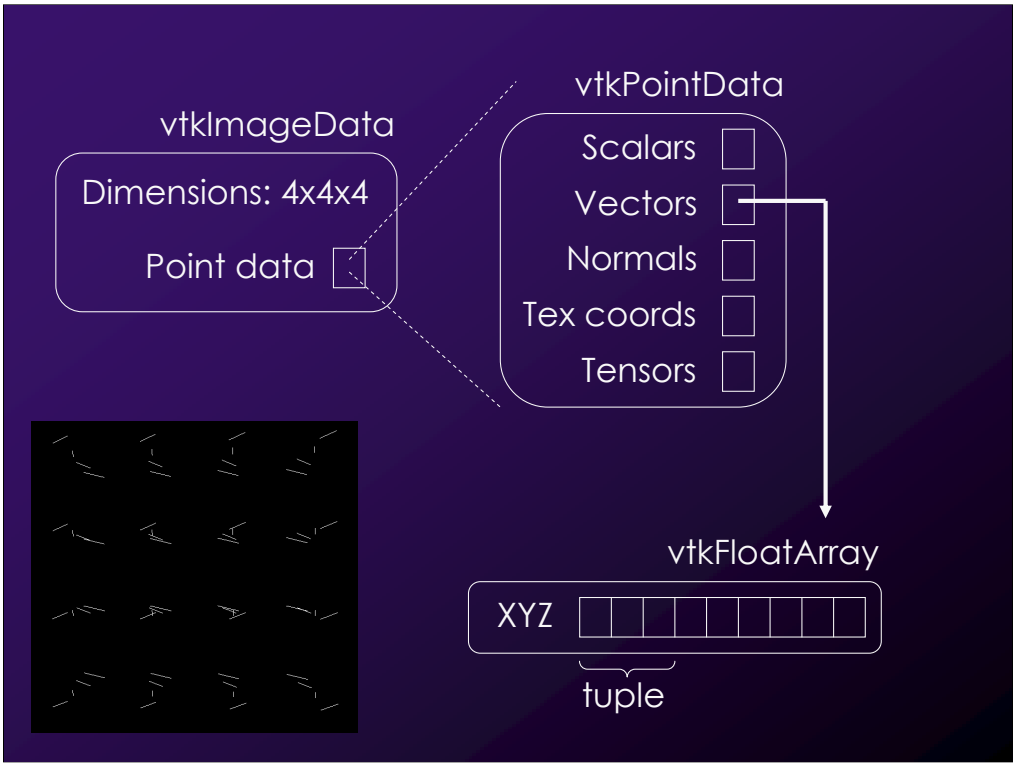
The point data is ”owned” by the polydata object. It has ”slots” for scalars, vectors, normals, etc. We can either use a pointer to a FloatArray in these slots, or we can choose to copy the data into the PointData object.

EXAMPLE



A 3D vector field is visualized using a "hedgehog"

The field is defined at regularly spaced locations in a volume



Since the data is regularly spaced, we can use a ImageData dataset. In VTK, ImageData can be both 2D and 3D, as long as it is regular and is aligned with the global coord axes.

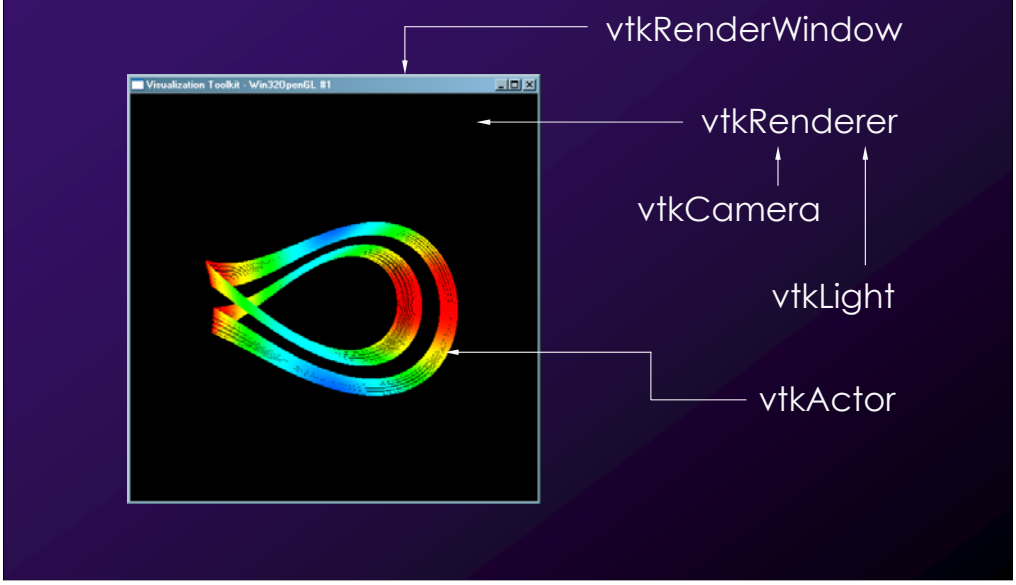
We specify that the number of samples in the dataset along each axis is 4x4x4. We then set a world-space spacing between each sample. This completely defines both the geometry and the topology.

What remains to be done is to assign the ”attribute data” (or ”point data”) at each point.

Again, the 3D vectors to be assigned to the points are stored in a FloatArray. Here, we need 3 floating-point values per geometry point. These 3 values are referred to as a **tuple**.

All datasets in VTK use the vtkPointData class to assign attribute data to points. In this case, we want to store a vector at each point, so we use the ”vector” slot of the PointData class.

HOW IMAGES ARE CREATED



PROPS AND ACTORS

Prop ≡ Something that can be drawn

Actor ≡ A prop that can be transformed

There are 2D and 3D actors

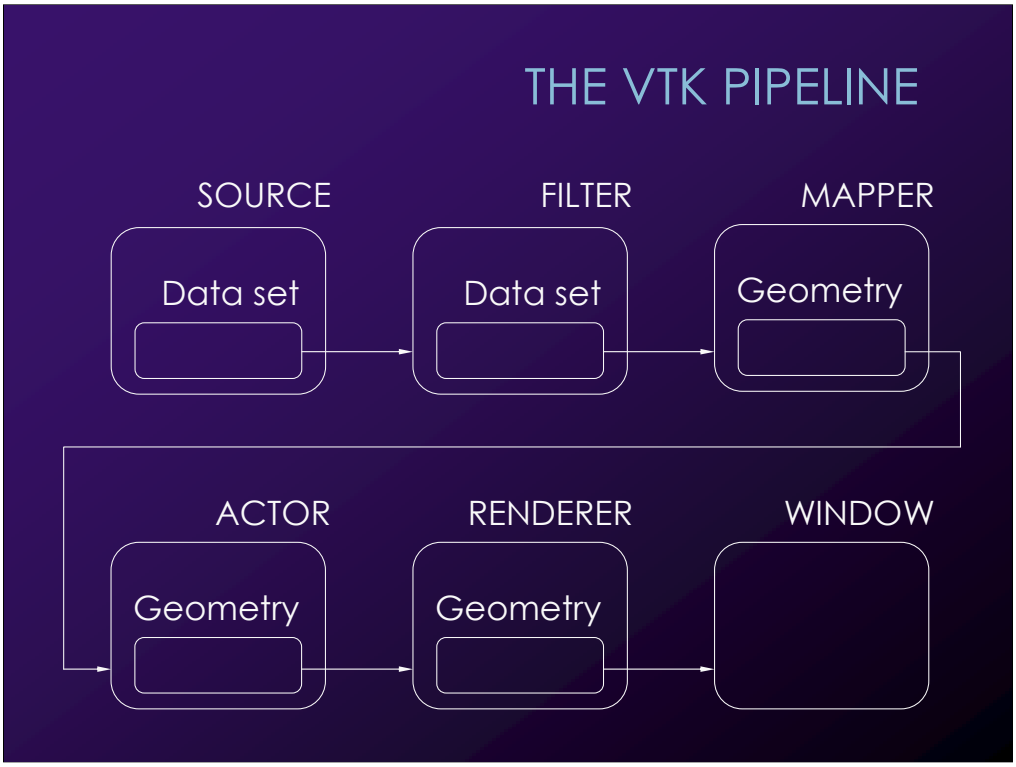
Each actor has one property:

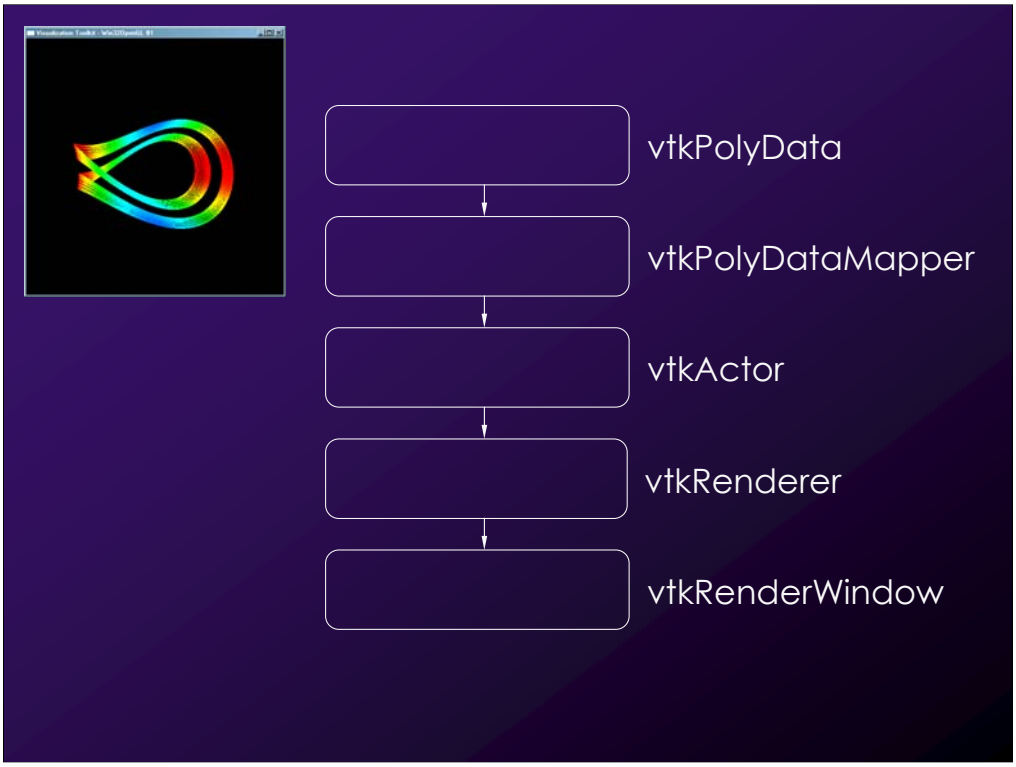
Property ≡ Collection of settings for surface material, opacity, etc.

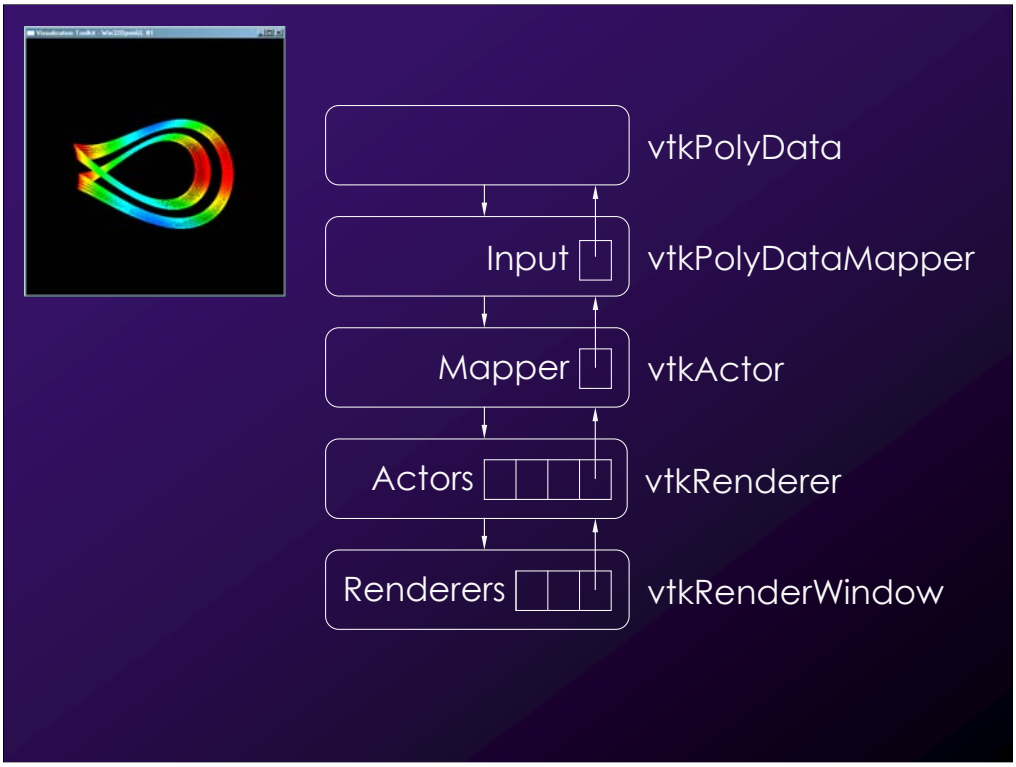
FILTERS AND MAPPERS

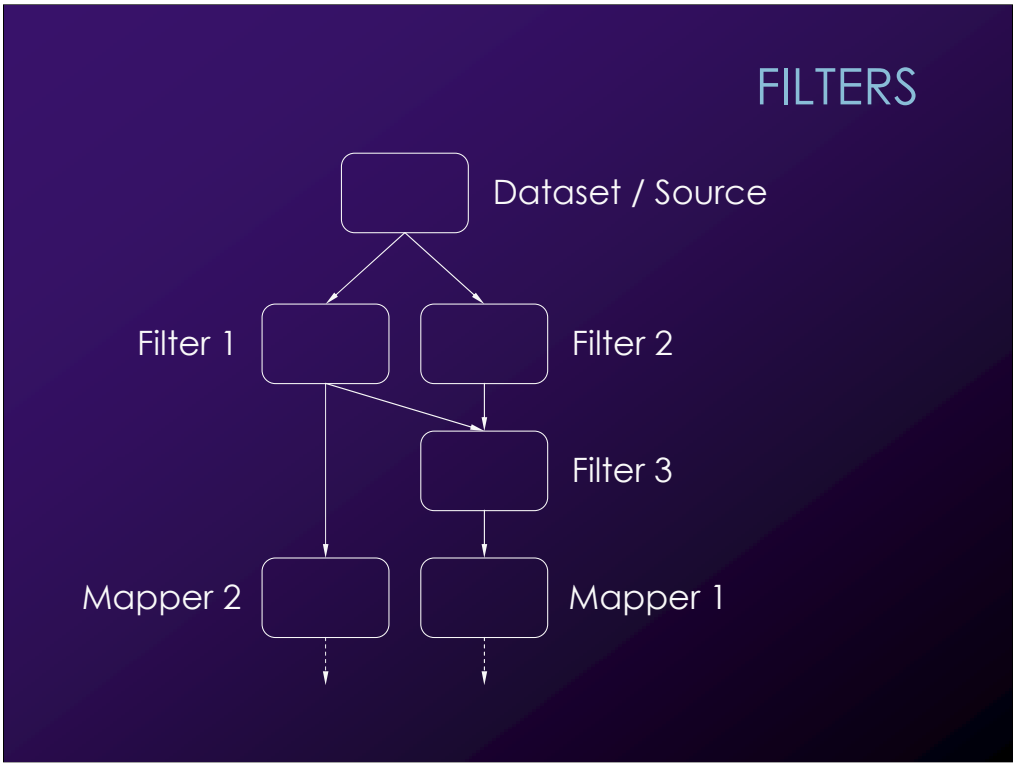
Filter ≡ Object that converts a dataset into a different dataset or performs operations on a dataset

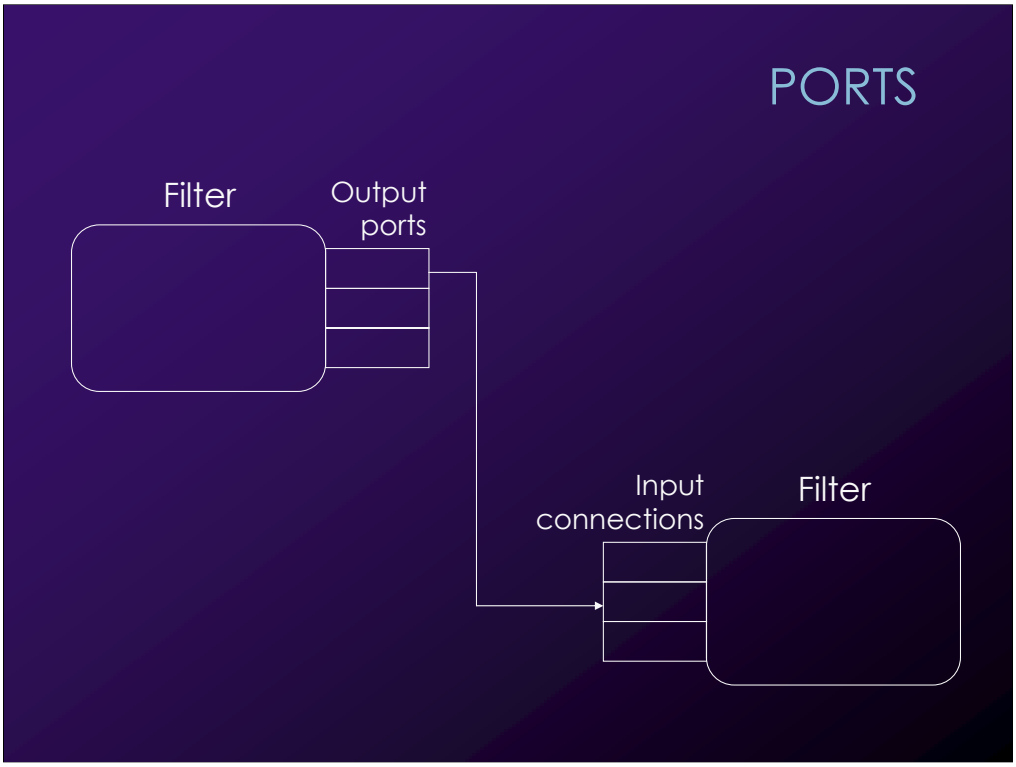
Mapper ≡ Object responsible for converting datasets into a form suitable for actors


THE VTK PIPELINE
SOURCE
FILTER
MAPPER
Data set
Data set
Geometry
ACTOR
RENDERER
WINDOW
Geometry
Geometry


vtkPolyData
vtkPolyDataMapper
vtkActor
vtkRenderer
vtkRenderWindow


vtkPolyData
Input
vtkPolyDataMapper
Mapper
vtkActor
Actors
vtkRenderer
Renderers
vtkRenderWindow


FILTERS
Dataset / Source
Filter 1
Filter 2
Filter 3
Mapper 2
Mapper 1


PORTS
Filter
Output ports
Input connections
Filter

PORTS

All pipeline objects have ports

Whether an input port is **repeatable**, i.e., if you may connect more than one output to it depends on the object

Errors are detected at run-time

PORTS

There are two ways to connect objects

The old syntax still works but is discouraged

It doesn't "know" about multiple inputs

The assignment intermingles both ☹

MEMORY MANAGEMENT

VTK uses reference counting

Don't use **new** to create objects!

```
vtkActor* actor = vtkActor::New();
                  ...
                actor->Delete();
```

MEMORY MANAGEMENT

The object may or may not be deleted when you call **`Delete()`**

If you have assigned the object to another object (e.g., via a port) it is not

When **VTK methods** are used to assign, a reference counter is increased

When **`Delete()`** is called the counter is decreased

MEMORY MANAGEMENT

When reference counter reaches 0
the object is deleted

BE CAREFUL!
Not true garbage collection
This code will break:

```
vtkActor* actor = vtkActor::New();
vtkActor* pointer = actor;
actor->Delete();
pointer->Render();
```