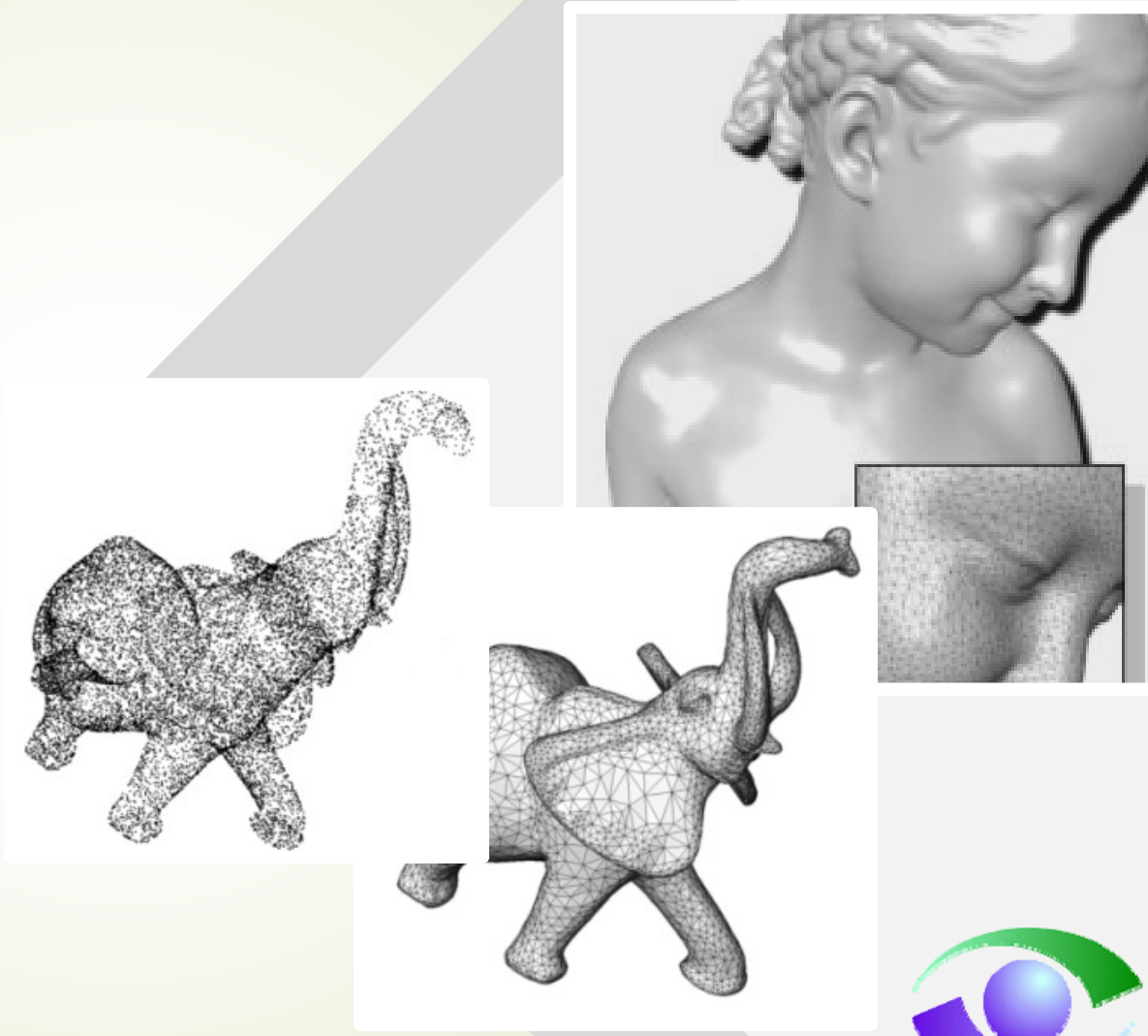
3D Reconstruction Using High Resolution Implicit Surface Representation and Memory Management Strategies



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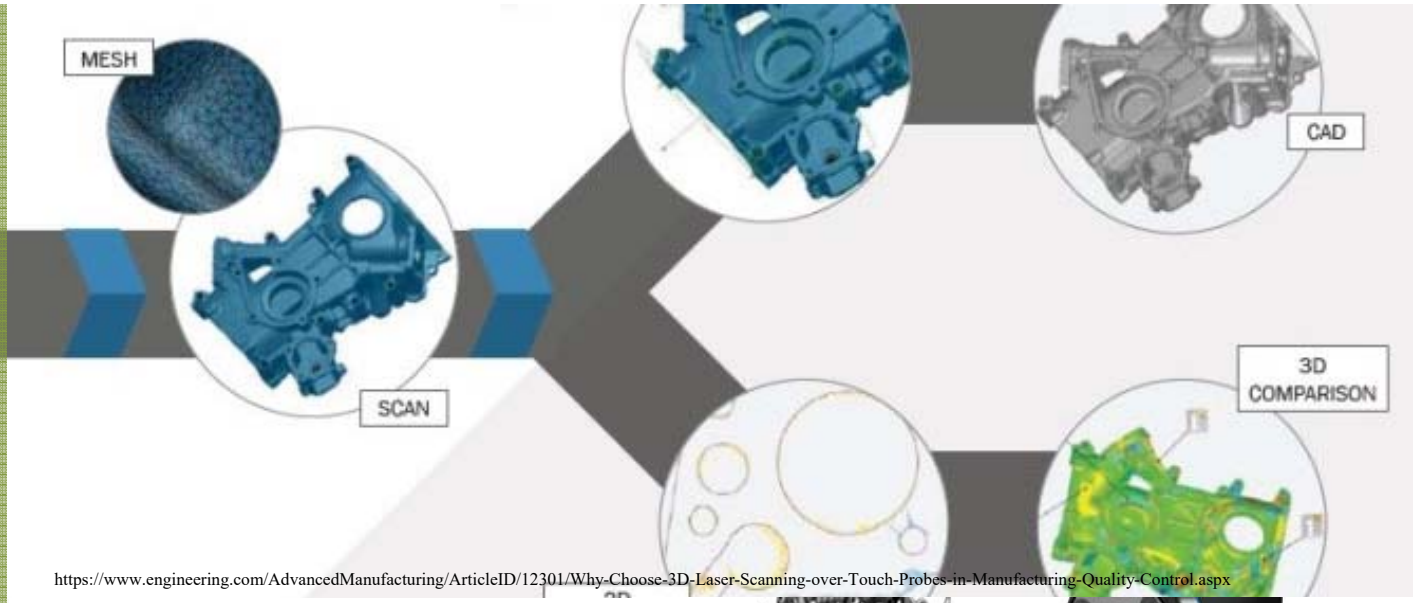
My PhD project is supported by the **CREAFORM** research chair.

CREAFORM is a world-class company founded in 2002. They develop, manufacture and distribute innovative portable 3D measurement technologies.

CREAFORM's 3D sensors rely on Vector Field 3D representation method.



https://www.engineering.com/AdvancedManufacturing/ArticleID/12301/Why-Choose-3D-Laser-Scanning-over-Touch-Probes-in-Manufacturing-Quality-Control.aspx

CREAFORM

https://www.creaform3d.com/en/metrology-solutions/handheld-portable-3d-scanner-goscan-3d

Vector Field Representation (Tubic et al, 2002)

- **A unique representation which allows registration, integration and visualization (all 3D modeling steps) to be achieved in real time.**
- **Achieve linear computational complexity for all 3D modeling steps.**
- **An implicit representation approach**

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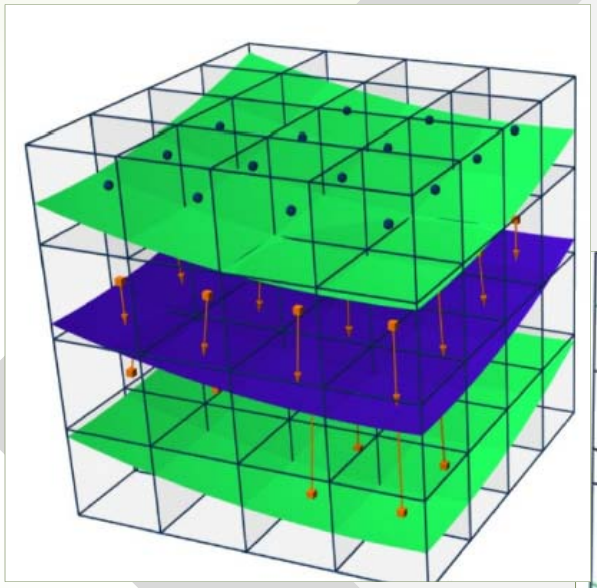
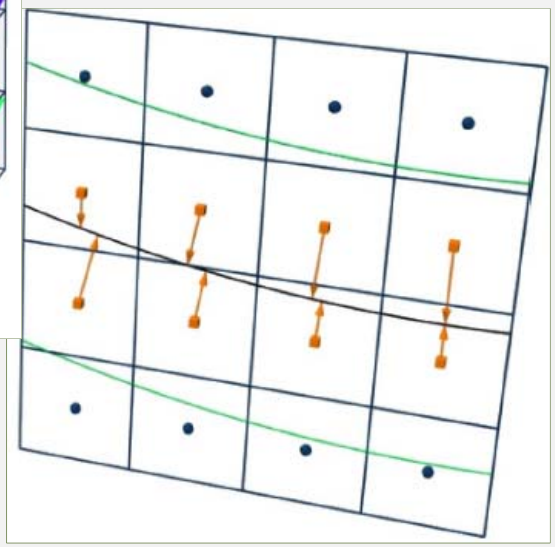
Vector Field Representation (Cont.)

- Each voxel provides the information on the vector point from the voxel center to the closest point.
- Encodes covariance of the points, the surface normal, distance between the voxel data and the plane
- A surface in each voxel approximated by a plane.

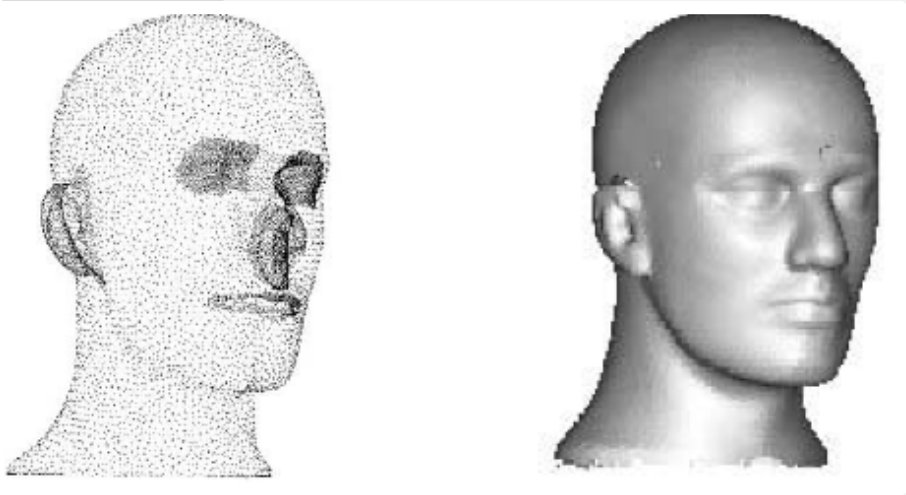


(Tubic,2006)



Vector Field Representation (Cont.)

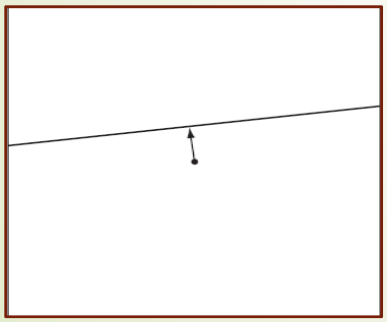
An explicit surface representation can be extract from the vector field surface representation.



Problem Statement

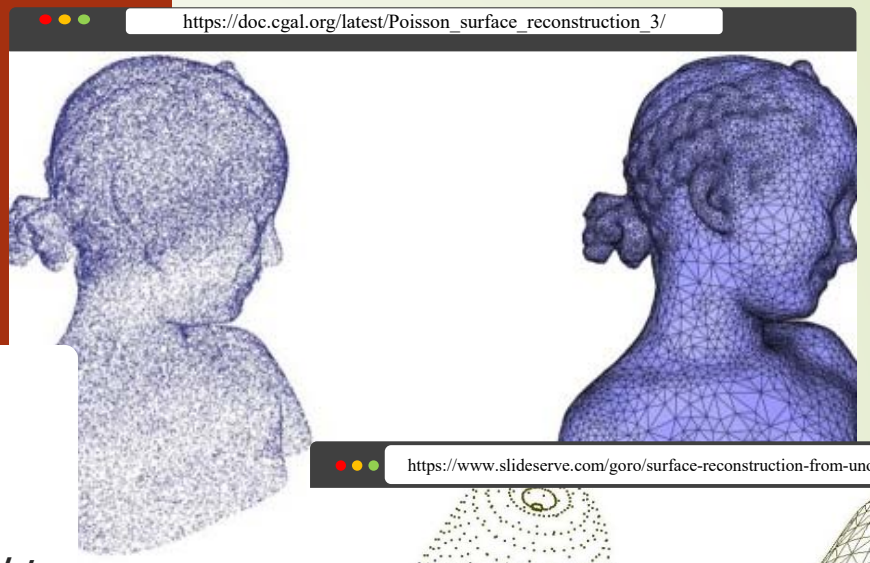
The vector field surface representation method is used by Creaform's hand-held 3D scanners. The Main problem with the current implementation of the vector field in the context of metrology :

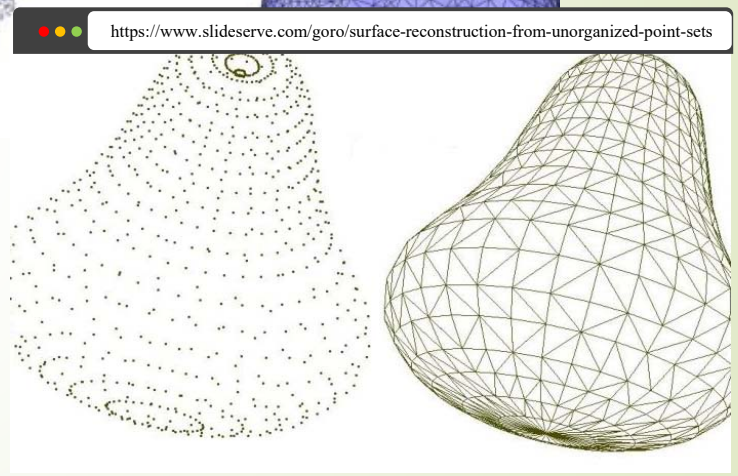
- **Approximating a surface by a plane**
- **Planar Approximation is not sufficient for describing small details**



Surface Reconstruction

Unstructured set of points need to be transformed into a meaningful digital representation of the scanned object.





Description of research objective

The overall goal of our project is to

- ✓ Propose a 3D reconstruction approach
- ✓ Providing an accurate and robust mesh everywhere on the surface

Research Methodology

There are two main solutions for solving the current problem as :

- Decreasing voxel size in the vector field framework.
- Identify the regions for which the planar approximation of the surface is not valid and, for these voxels, implement a high-order surface representation.

Decreasing Voxel Size in The Vector Field Framework

- Decreasing voxel size causes an increase in the number of voxels which increases memory requirement.
- Each voxel may not receive enough points.

Identify the regions for which the planar approximation of the surface is not valid and, for these voxels, implement a high-order surface representation

To achieve the main objective of our project we will :

- Identify in the vector field the regions that require a surface approximation that is better than a plane
- Refinement of the detected regions

Detect the voxels of the vector field for which the planar approximation is not sufficient.

- Vector field is used to build a planar approximation of surface.
- We claim to detect the regions for which the planar approximation in not sufficient by an analysis of the smallest eigenvalue of the covariance matrix

Voxel Detection

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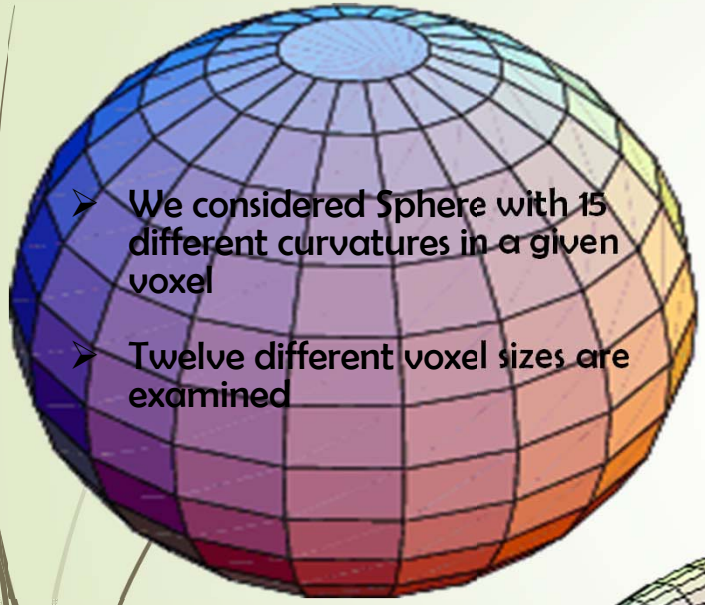
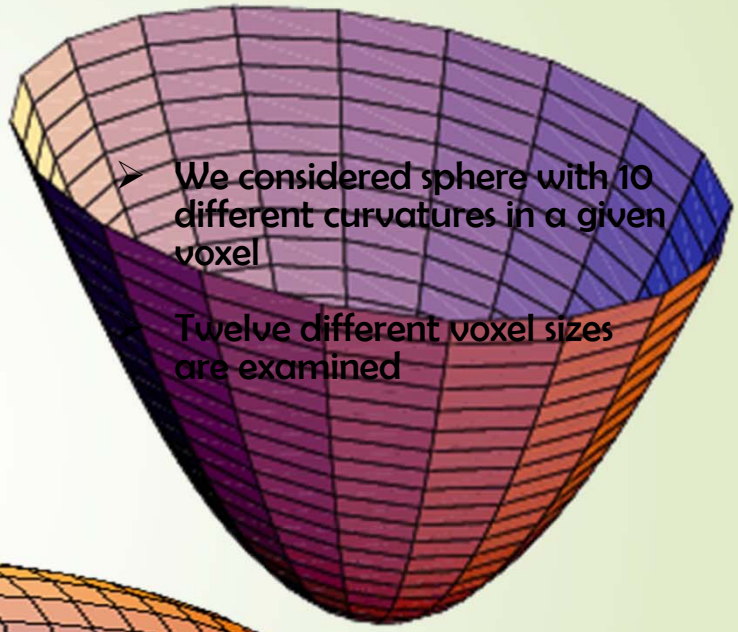
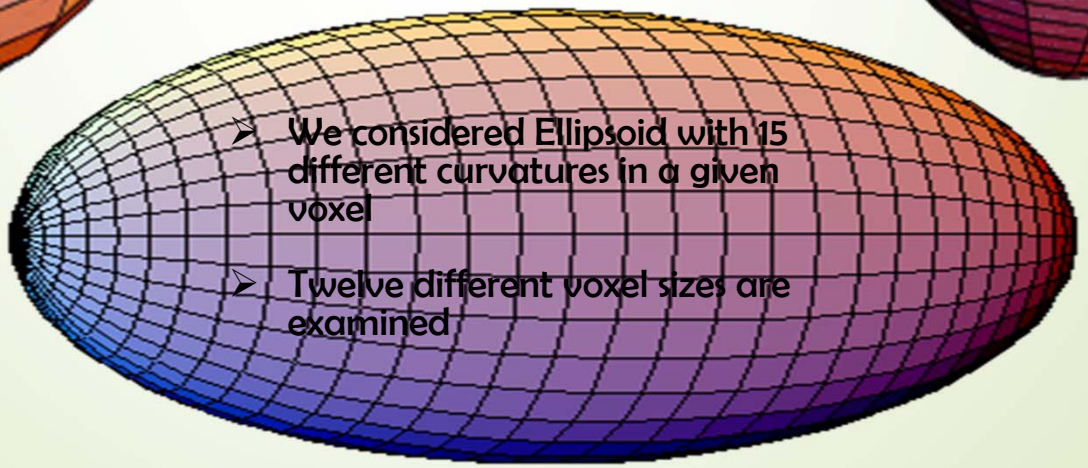
Preliminary result for the Sphere, Ellipsoid, Paraboloid



- We considered Sphere with 15 different curvatures in a given voxel
- Twelve different voxel sizes are examined

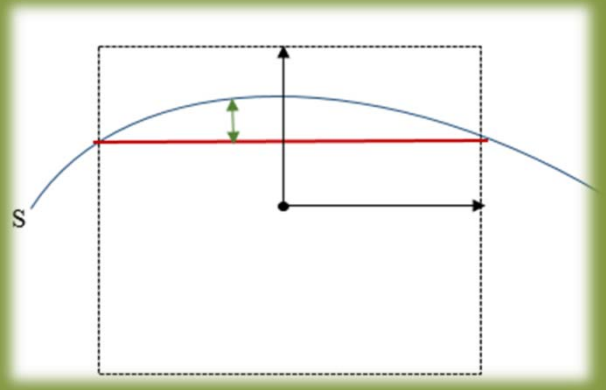


- We considered sphere with 10 different curvatures in a given voxel
- Twelve different voxel sizes are examined



- We considered Ellipsoid with 15 different curvatures in a given voxel
- Twelve different voxel sizes are examined

Preliminary simulation experiments on the analysis of the smallest eigenvalues of the covariance matrix in a voxel(Cont.)



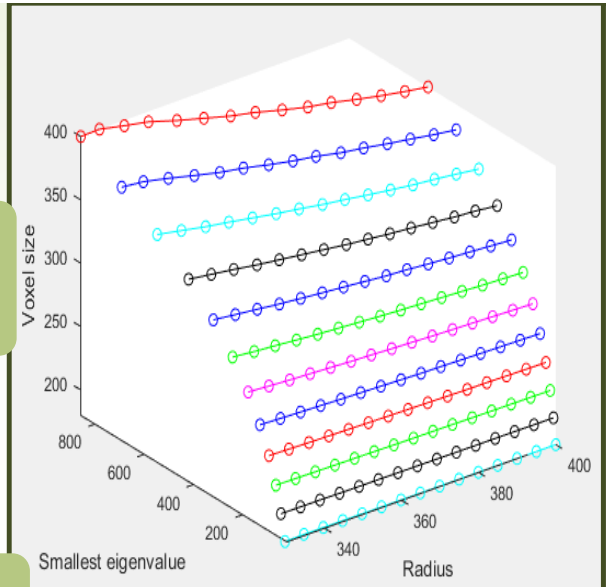
- Each type of desired surface with different curvature is considered for a given voxel size.
- The planar approximation error for each surface type with different curvature is computed.

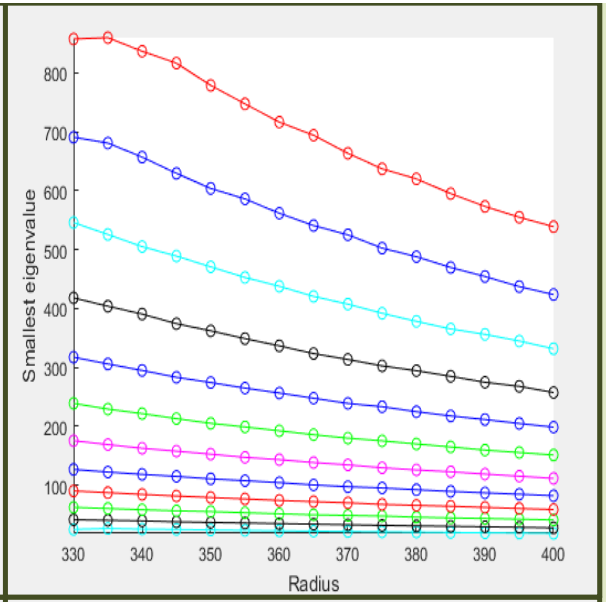
Preliminary result on the Sphere

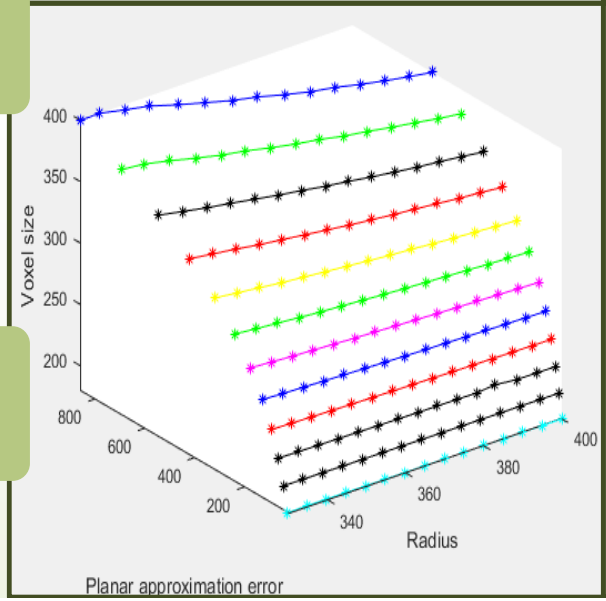
Representation of the relationship between the smallest eigenvalue and the radius of a sphere for different voxel sizes.

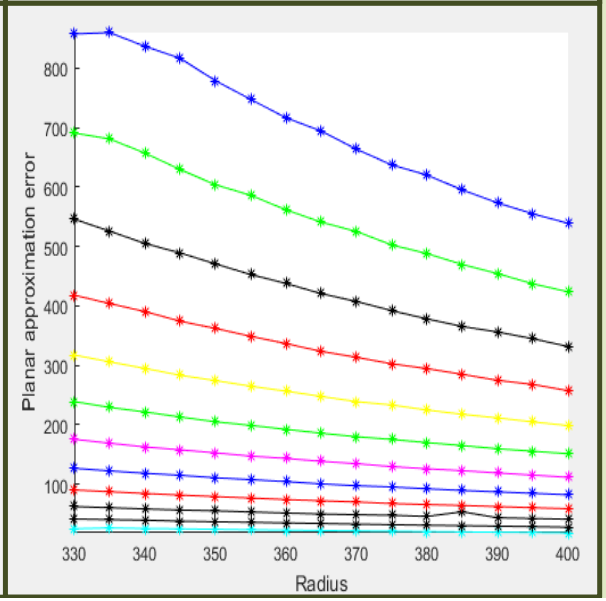
Each color represent a different voxel size. By increasing the voxel size the value of the smallest eigenvalue is also increasing.

Representation of the relationship between the planar approximation error and the radius of the sphere.



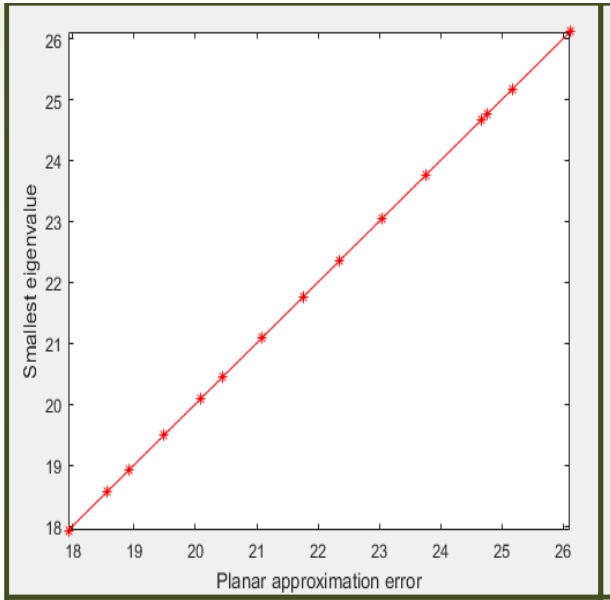


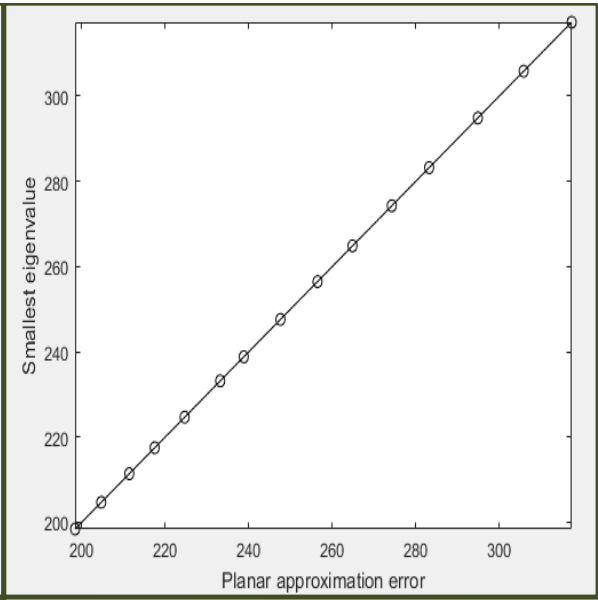


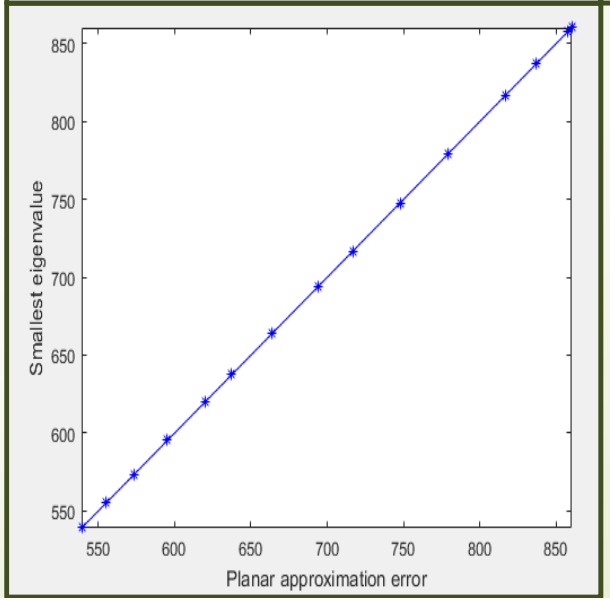


Preliminary result on the Sphere(Cont.)

There is a linear relationship between the planar approximation error and the smallest eigenvalue.







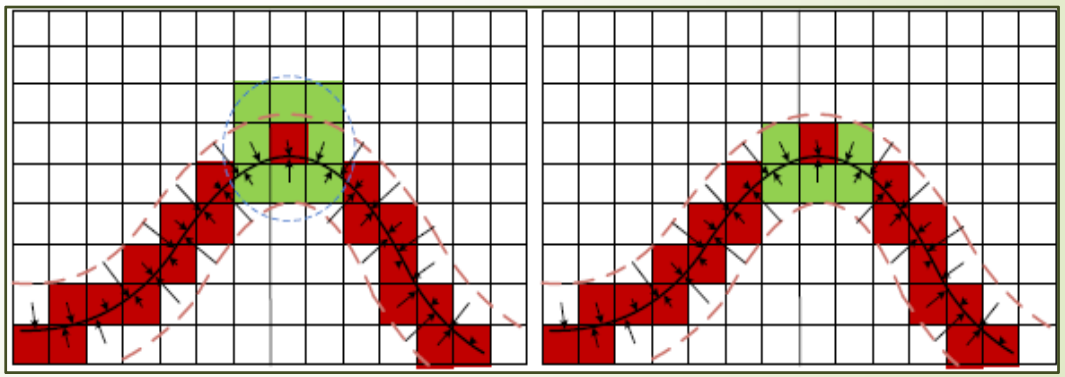
represent the voxel size 180

represent the voxel size320

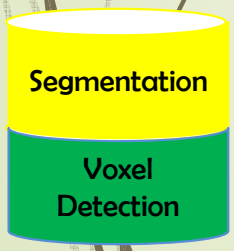
represent the voxel size 400

Segmentation of the regions for which the planar approximation is not valid in the vector filed framework

Segment the vector field into regions composed of the detected voxels for which the planar approximation fails.

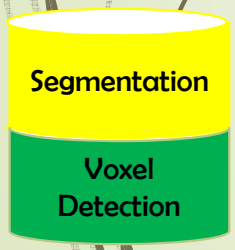


(Nguyen&Laurendeau,2012)



Segmentation of the regions for which the planar approximation is not valid (Cont.)

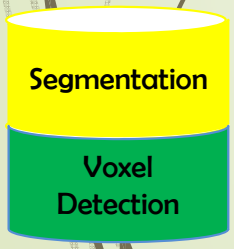
- Berkman and Caelli (Berkman & Caelli, 1994) proposed a curvature-based approach which uses covariance-based curvature estimation instead of surface patching (Besl & Jain, 1986).
- Adapt these old references in the vector field framework is a challenge in our project.
- This reference (Wu, P, 2017) demonstrate that the covariance technique is equivalent with differential geometry technique.
- Choosing Berkman and Caelli's approach is natural since the covariance matrix is available in each voxel in the vector field.



Segmentation of the regions for which the planar approximation is not valid

	K		
H	+	0	-
-	Peak	Ridge	Saddle ridge
0	None	Flat	Minimal surface
+	Pit	Valley	Saddle valley

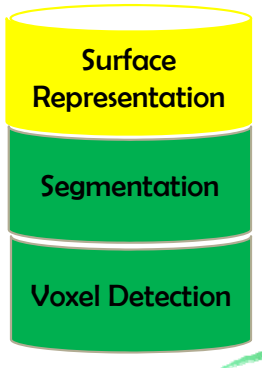
- Different surface type classified as a function of the sign of the Gaussian and mean curvature.



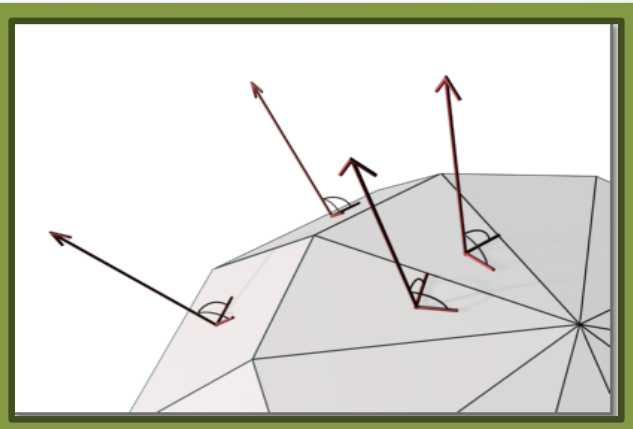
Finding a high order surface representation for the segmented regions

Choose an appropriate representation method for the surface in the segmented region :

- NURBS (Non-Uniform Rational Basis Spline)
- Poisson Surface Reconstruction



Investigating continuity between the segmented voxels and their neighbors



https://knowledge.autodesk.com/support/3ds-max/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/3DSMax/files/GUID-41B1C829-4551-4274-8F8C-D860C0810DAE-htm.html

Investigating the continuity between the segmented voxels and their neighbors for which the planar approximation is sufficient

- Check the change in the normal.
- Blending the regions with high order representation with those for which the planar approximation is sufficient.

Continuity Investigating

Surface Representation

Segmentation

Voxel Detection

Thanks For Your Attention