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Extraction of axis of bent pipe from 3D scanned data

Junghyun Ryu
Sungmoon Joo, Jinbok Choi
Kijang Research Reactor Design and Construction Project, KAERI

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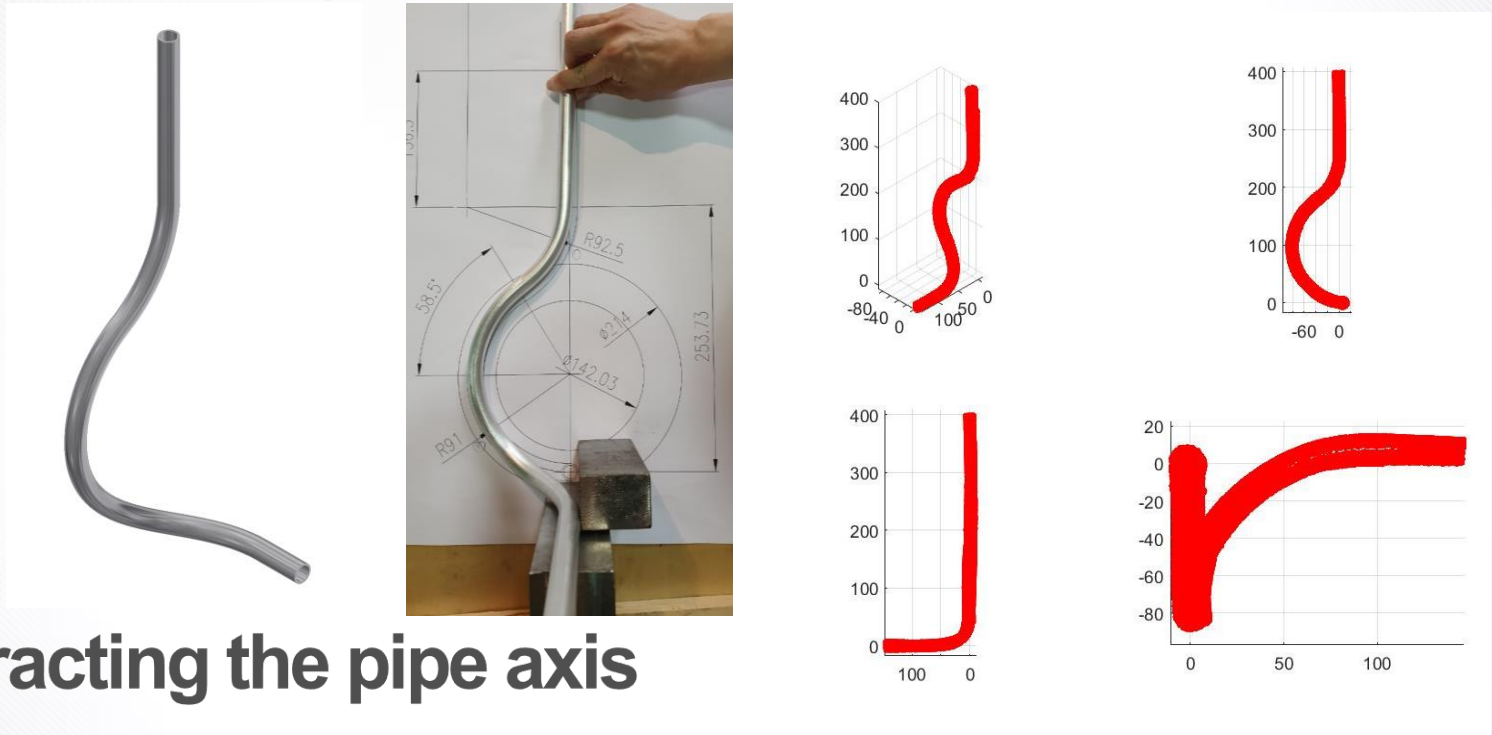
01 Introduction

01 Introduction

Objective shape for the 3D scan



Extracting the pipe axis

- Extracting the pipe axis is a key feature to construct the 3D cad model because the cross section of the objective for this study is uniform .
- The pipe axis is extracted by minimizing the root mean square of the inner product between the pipe axis and the normal vector on 3D scanned data.

02 Methods and Results

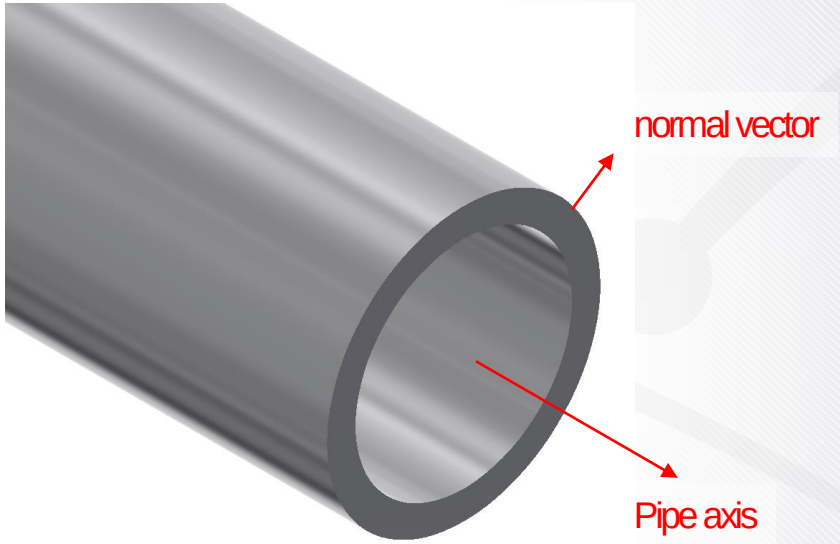
Methods and Results

Reverse engineering procedure

Step 1. 3D canned data

- property float x
  property float y
  property float z
  property uchar red
  property uchar green
  property uchar blue
  property float nx
  property float ny
  property float nz
  end_header
  46.332 126.438 505.309 134 134 134 -0.548528 -0.429211 -0.717561
  3.08638 242.428 524.824 50 50 50 -0.82464 0.118223 -0.553166
  24.8162 161.525 512.022 55 55 55 0.433423 0.519119 -0.736655
  84.8726 40.1625 488.436 218 218 218 -0.62039 0.16837 -0.766008
  25.5832 161.202 512.363 55 55 55 0.469991 0.516492 -0.715782
  82.1737 34.6244 497.841 26 26 26 -0.871299 0.0946144 0.481545
  26.5304 161.284 512.985 47 47 47 0.366299 0.508301 -0.779394
  88.2003 39.8421 487.891 255 255 255 0.044058 0.194093 -0.979993

coordinate color normal vector



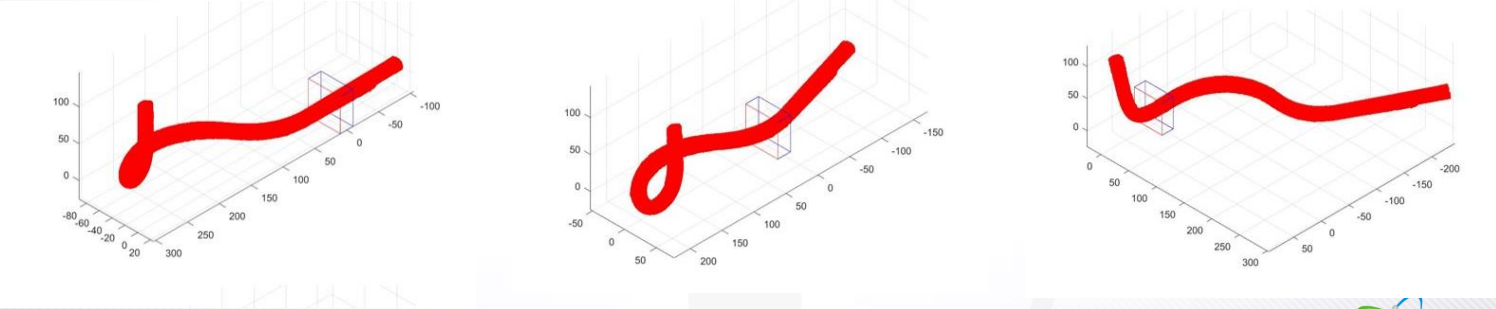
- Inner product between pipe axis and the normal vector is zero!
- however, in the real measurement, it should be noted the measurement error always exits.
- Thus, the vector, which minimize the root mean square of the inner product between the normal vectors, could be a simple and robust approximation for the pipe axis direction.

02 Methods and Results

Reverse engineering procedure

Step 2-1. setting ROI to minimize the error from the curvature

- Coordinate on axis: average coordinate values in ROI
- Direction of the axis: calculated by the Newton-Raphson procedure.
- Trade-off the length of the ROI is essential because
  too short ROI could not effectively suppress the measurement error and
  too long ROI will induce the error from the curvature of the objective shape.
- In this study, the length of the ROI is 20 mm.
- The relative position between ROI and scanned data is updated systematically
  using the information for the axis direction



02 Methods and Results

Reverse engineering procedure

Step 2-2. Objective function and it's derivatives for the Newton-Raphson procedure

- Objective function for the minimization

$$f = v_k^T N_{km}^T N_{mn} v_n + \lambda\left(v_n^T v_n - 1\right)$$

N_{ij} is a group of normal vectors
i indicated the index of the points
j indicated the index of the points
v_i is component of the vector for the axis direction

- 1st derivatives

$$\frac{\partial f}{\partial v_i} = 2N_{im}^T N_{mn} v_n + 2\lambda v_i = 0$$

$$\frac{\partial^2 f}{\partial \lambda^2} = v_n^T v_n - 1 = 0$$

- 2nd derivatives

$$\frac{\partial^2 f}{\partial v_i \partial v_j} = 2N_{im}^T N_{mj} + 2\lambda\delta_{ij} \qquad \frac{\partial^2 f}{\partial v_i \partial \lambda} = 2v_i$$

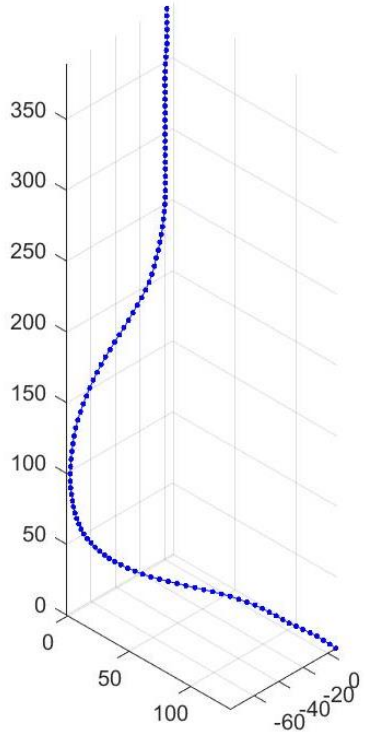
$$\frac{\partial^2 f}{\partial \lambda \partial v_j} = 2v_j \qquad \frac{\partial^2 f}{\partial \lambda^2} = 0$$

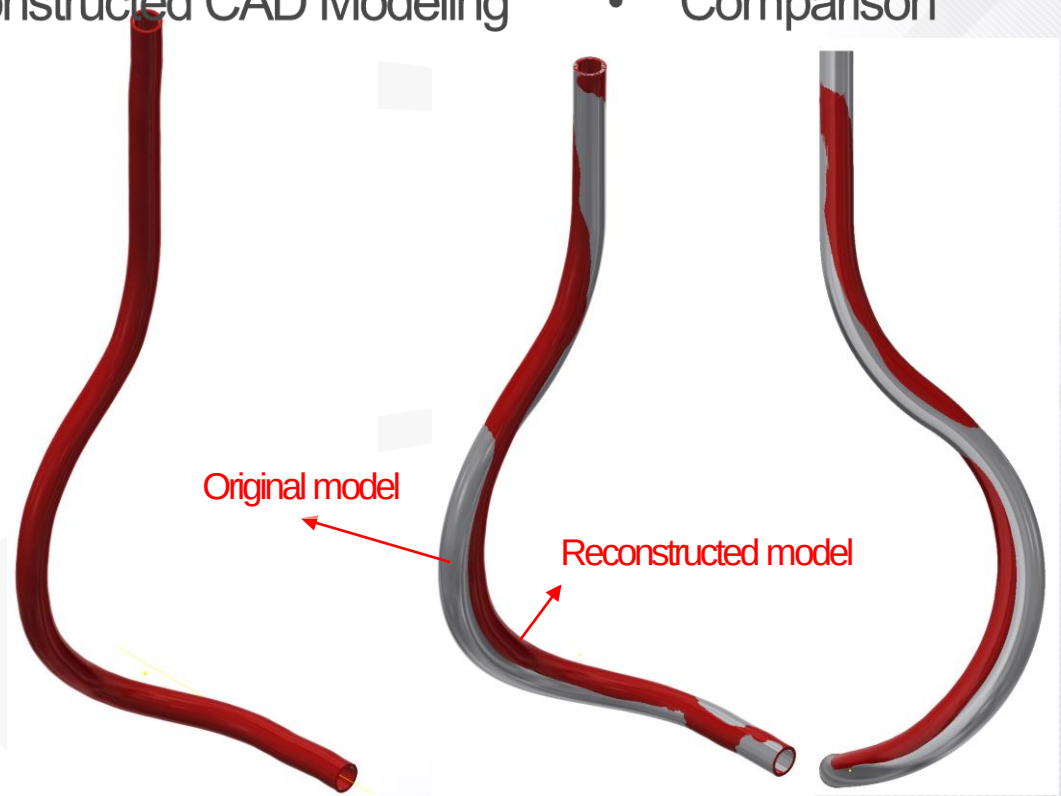
02 Methods and Results

Reverse engineering procedure

Step 3. Reconstructing the 3D model using the sweep method with the known cross-section information and reconstructed axis spline line.

- Scanned Data
- Reconstructed CAD Modeling
- Comparison





03 Conclusions

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- Points on the pipe axis are successfully extracted from the scanned data.
- Short height of ROI is adopted to minimize the effect of the curvature and the relative position between ROI and scanned data is updated systematically using the information for the axis direction.
- The axis directions are calculated by minimizing the square sum of the inner product between the vector for the axis direction and normal vectors on the scanned points.

04
Acknowledgement & References

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Acknowledgements

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References

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THANK YOU