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# 3D SURFACE MESH ESTIMATION CHALLENGE

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# INTRODUCTION TO ULTRASOUND BASED NON-DESTRUCTIVE TESTING (NDT)

# BACKGROUND TO ULTRASOUND BASED NDT

- Ultrasound has become one of the most common imaging modalities in the past two decades in fields such as sonar, biomedical imaging, and non-destructive testing (NDT).
- Ultrasonic waves in NDT are used to inspect and evaluate the integrity of different parts and materials, from rockets and jet engines to critical infrastructure like pipes and wind turbines.
- Computer vision and image analysis are routinely used to detect and characterize flaws, cracks, and other hazardous or dangerous defects.
- Early detection of issues and dangers in components helps save billions of dollars annually worldwide, and prevents catastrophic impacts to life and the environment.
- These methods help ensure the safe operation of aircrafts, concrete structures, railways, and critical infrastructure in energy production that we rely on as a society.

# COMPUTER VISION IN NDT

- Computer vision techniques in NDT have advanced quickly in the past few years.
- While traditional techniques remain useful, modern ultrasound devices can easily collect vast quantities of high-resolution data in a short amount of time, making them approachable by deep learning methods.
- For example, a continuous acoustic scan at sub-millimetric resolutions of the full circumference of a pipe that is multiple kilometers long can yield millions of images in a few hours.
- Such datasets may contain their own unique challenges, including extreme data imbalance, or the need for multi-task, weakly-supervised and semi-supervised learning.
- In addition, gaps remain between natural image-derived deep learning algorithms, and those for ultrasonic acoustic-derived images, including focused image denoising, image interpretation, uncertainty quantification, and automated system self-awareness.
- Research into these topics is therefore important for developing robust deep-learning applications in NDT.

# ULTRASOUND IN NDT

- In the last few years, the medical ultrasound field has witnessed the successful application of deep learning in both in 2D and 3D to enhance, identify, and significantly speed up the analysis process.
- However, in the field of NDT, ultrasound analysis comes with its own set of challenges. For example, the imaging media and conditions can be significantly less predictable than the human body, and therefore many medical ultrasound analysis methods cannot be applied immediately to NDT ultrasound data.
- Therefore, methods specifically for the NDT domain are thus of paramount importance to keep up with the increasingly complex demands in NDT.

# CVPR 3D SURFACE MESH ESTIMATION CHALLENGE

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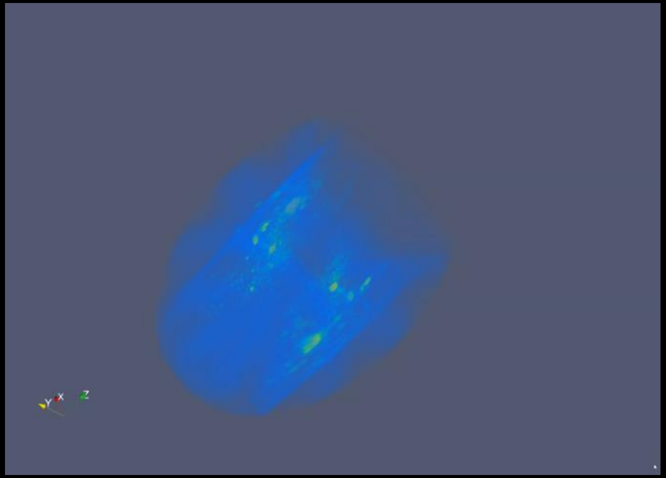
# CVPR CHALLENGE INTRO

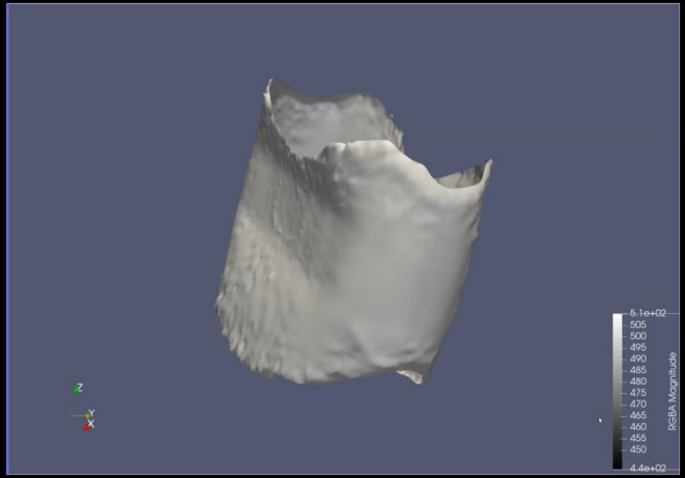
- Surface estimation is crucial in industrial ultrasound image analysis as it separates the scanned object's surface from background noise and artifacts such as spurious refractions and other reverberations.
- Accurate surface estimation not only provides better visualization, but also ensures increased accuracy in measurements crucial for NDT tasks such as
  - defect/flaw identification
  - detection
  - characterization
- This was a challenge set for a special session on Deep Learning for Ultrasound applications in the 2023 CVPR conference
  - https://www.cvpr2023-dl-ultrasound.com/
- The Hackathon Challenge Description is in the following Section

# CVPR TRAINING DATASET

- A training dataset is provided which consists of 5 labeled ultrasound volumes and 85 unlabeled
- Each volume is a separate scan containing a piece (or connected pieces) of steel pipe, with or without an object inside the pipe, and with or without debris/dirt debris/dirt at the bottom of the pipe.
- The labels are in the form of the 5 corresponding surface meshes, which were manually cleaned by an experienced data analyst.



Example volume image
(size: 768*768*1280)




Example surface mesh
reference

# CVPR CHALLENGE EVALUATION

- An evaluation set of 10 meshes & volumes is also provided
- Your solution should be evaluated using the Chamfer & Direct Hausdorff distances, which can be implemented using the Nvidia KAOLIN package and Scipy
- Other evaluation metrics include
  - F1 score with different radii
  - Mean surface distance
  - Residual mean square distance
- A demo jupyter notebook is provided with examples of implementing these metrics

Chamfer Distance

$$\frac{w_1}{|P_1|}\sum_{p_{1i}\in P_1}\min_{p_{2j}\in P_2}(||p_{1i}-p_{2j}||_2^2)+\frac{w_2}{|P_2|}\sum_{p_{2j}\in P_2}\min_{p_{1i}\in P_1}(||p_{2j}-p_{1i}||_2^2)$$

Direct Hausdorff Distance

$$d_{\mathrm{H}}(X,Y)=\max\left\{\sup_{x\in X}d(x,Y),\ \sup_{y\in Y}d(X,y)\right\},$$

# UBC DATA SCIENCE CLUB HACKATHON CHALLENGE

# HACKATHON CHALLENGE DESCRIPTION

- The previous slides described the challenge set for a special session on Deep Learning for Ultrasound applications in the 2023 CVPR conference
  - https://www.cvpr2023-dl-ultrasound.com/
- Below is a link to one of the solutions applied to the provided dataset
  - https://github.com/lisatwyw/smrvis
  - Report located under: log/Report.pdf

- Hackathon Challenge
  1. Given the data and code provided, recreate this solutions
  2. Comment on the feasibility and viability of this solution for the challenge
  3. Optionally attempt your own solution, potentially using a more modern deep learning architecture (such as an image segmentation approach)

# CHALLENGE RULES

- Redistribution or transferring of competition data or data links is not allowed during or after the competition.
- Participants should use the data only for this competition. If the participant wants to access, redistribute, or transfer the Dataset for any other purposes, they should contact DarkVision for permission.