3D Torso Image Retrieval of Prior Patient Cases Using Unsupervised Learning for Informed Decision-Making about Breast Reconstruction Surgery

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INTRODUCTION

- Use of three-dimensional (3D) surface imaging is growing in assisting plastic surgeons with assessing breast reconstruction outcomes and surgical planning.
- 3D images of prior patients from comprehensive databases can be used as reference cases during medical consultations to effectively tailor treatment plans to each patient's needs.
- However, retrieving reference cases becomes challenging as database size increases, with preoperative demographic or clinical queries often failing to match breast shapes and torso silhouettes.
- Previous 3D image retrieval methods require predefined rankings of all images, which is time-consuming for large databases, while unsupervised learning methods for image retrieval are limited to 2D images[1].
- Here, we propose an unsupervised machine learning framework to learn discriminative features from 3D images of past patients and retrieve similar cases to query images.

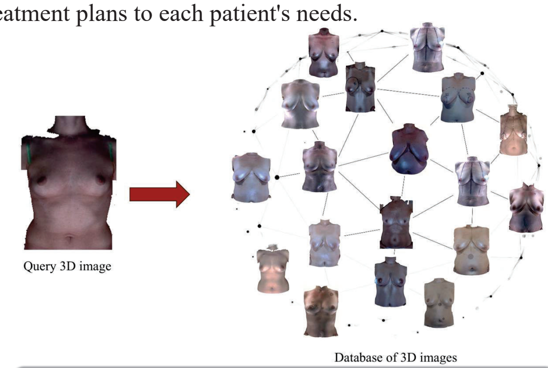

Figure 1. 3D image retrieval from comprehensive databases.

DATASET

- We used 471 raw 3D photographs taken preoperatively at baseline before breast reconstruction.
- We define a breast state for each patient from their medical records describing their breast at baseline, e.g., native-breasts, bilateral-mastectomy, etc. based on the longitudinal step of reconstruction.
- Breast state and BMI category at baseline were used to define 37 different classes in our dataset characterizing each patient.
- The dataset was randomly sampled by class to ensure balance. Classes containing one image were allocated to the training set, ensuring the representation of rare cases.
- We split the data into 3 parts: 70% of the data for training, 10% for validation, and 20% for testing.

METHODS

- We propose an unsupervised machine learning framework consisting of a feature extractor utilizing the 3D convolutional neural network backbone CurveNet[2] to encode images as unit feature vectors.
- A regularly updated memory bank stores and optimizes the representation of patient images during training.
- This framework learns optimal feature embeddings via instance-level discrimination by providing a distinct representation for each training image.
- Inference is performed by computing a feature vector for a query image and retrieving k-nearest neighbors in the memory bank with high cosine similarity.
- Accuracy was measured using top-k classification, which identifies the top-k images similar to the query image from the memory bank and then averages the number of correct class matches.

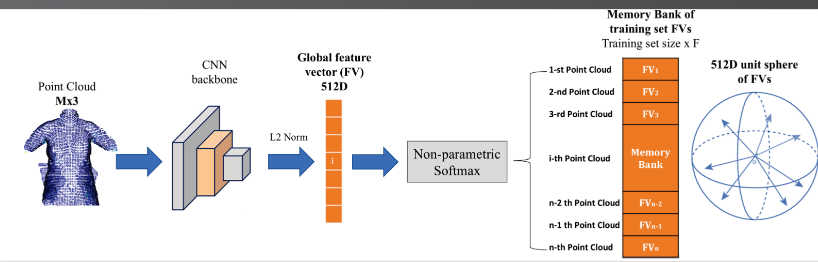

Figure 2. Pipeline of the proposed approach. The optimized feature representation of patient images is learned via instance-level discrimination by maximally scattering the features of the training set over the 512-dimensional unit sphere.

RESULTS

- A nearest neighbor search in the unoptimized feature vectors of the training set reaches a top-1 accuracy of 3.9%.
- An increase in the top-1 accuracy, reaching 15.7% in the testing set is reported.
- The top-5 accuracy reaches 43.2% in the testing set.
- We report improved discrimination despite noisy vertices and absence of explicit training objective.

CONCLUSIONS

- The proposed unsupervised learning framework demonstrates promising results in 3D torso image retrieval for breast reconstruction surgery.
- These preliminary results indicate that our model improves at learning to discriminate between the different images in the memory bank after training.
- The framework learns a discriminative feature representation of images despite the noisy vertices from irrelevant surfaces (e.g., imaging table and patients' arms and legs) in the raw images and the absence of a training objective in unsupervised learning.

FUTURE DIRECTIONS

- Our future work will address the following:
  - Removing noisy vertices from the dataset images outside of the chest region to enhance performance.
  - Assessing performance using medically relevant validation metrics such as the medical appropriateness score.
  - Exploring semi-supervised learning approaches to improve accuracy using dataset classes.
- The proposed framework can provide a dataset to build a generative model for breast shape simulations of surgical outcomes during each step of the reconstruction.

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References:

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