# Photogrammetric Orientation of Angiogram and CT Imagery to Support Transcatheter Aortic Valve Implantation


**Jeffrey Johnson, Luc Nicolet, Seema Mustaqeem, Matthew Travaglini**

Schulich School of Engineering, University of Calgary


## ABSTRACT


This capstone project presents an innovative approach to improving the Transcatheter Aortic Valve Implantation (TAVI) procedure. Our team has developed a novel program that autonomously computes the coordinates of fiducial markers from medical DICOM imagery, which are then sent to the space resection code to determine the angles of the C-Arm X-ray machine. By providing doctors with an efficient and precise means of obtaining a view of the patient's anatomy, our solution minimizes the need for the potentially harmful fluoroscopic dye that is typically administered during the TAVI procedure. This enhanced efficiency and precision enable smoother and more successful insertion of the prosthetic valve into the aorta, thereby reducing the risk of the procedure and increasing its viability for a greater number of patients. Our findings suggest that this technology has the potential to significantly improve the outcomes of TAVI procedures, ultimately enhancing the quality of life for many patients.


## INTRODUCTION

TAVI is a procedure used to treat aortic stenosis. During the TAVI procedure, fluoroscopic angiogram imagery is collected to aid in the placement of a prosthetic valve. Obtaining an optimal view of the aorta in the angiogram is crucial to the success of the procedure. Pre-operative computed tomography (CT) of the aortic valve can be used to estimate the orientation of the angiogram view using photogrammetric methods. The goal of the project is to develop a program that can compute coordinates of markers from medical DICOM images to input them into a space resection that can compute the angiogram angles using CT and fluoroscopic image datasets provided by a cardiothoracic radiologist.

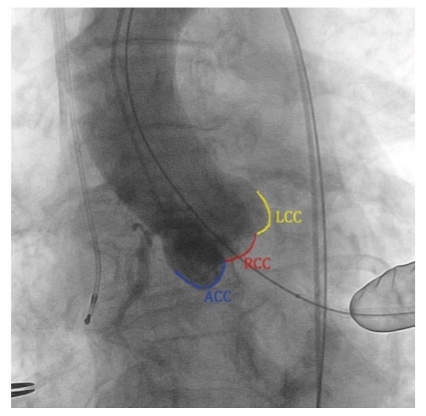

**Figure 1:** Fluoroscopic aortogram with contrast agent to confirm proper implantation plane in TAVI [1]

## CONTACT INFORMATION


Matthew Travaglini

Email: matthew.travaglini@ucalgary.ca

Phone: 587-500-8751


## MATERIALS AND METHODS

### Materials

- MATLAB (Space Resection, Point Identification, DICOM file loading)
- Python(Space Resection)
- Philips Medical AlluraXper (Fluoroscope)
- Siemens SOMATOM Force (CT Scanner)

### Methodology

- BB Pellets placed on patients' skin
- Pre-operative CT Scan taken
- BB identification in CT images
- Patient in OR
- Fluoroscopic images taken
- BB identification in Fluoroscopic imagery
- Space resection to determine C arm alignment

## RESULTS

### Space Resection

The developed program was able to successfully converge and compute the fluoroscopes orientation, as well as its precision and using back projection and comparing expected vs. computed fluoroscopic output.

The resultant orientation values showed some deviation from expected camera location. The expected rotation angles were [0, 0, 180] degrees, while the expected translation was [0, 0, 800] mm. This deviated significantly from the results of [20.2, -5.4, 179.0] degrees in rotation and [561.5, -495.61, 620.91] mm in translation. The adjustment in rotation could be attributed to the control measurement orientation. While a translation of ~500mm from expected seems large it could be explained based on the size of the C-Arm/CT machine, and an adjustment in coordinate origin.

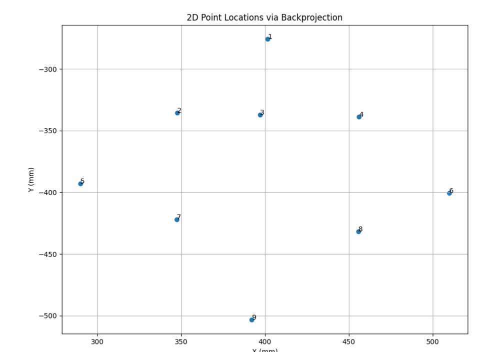

**Figure 2:** 2D Point Location from collinearity equations

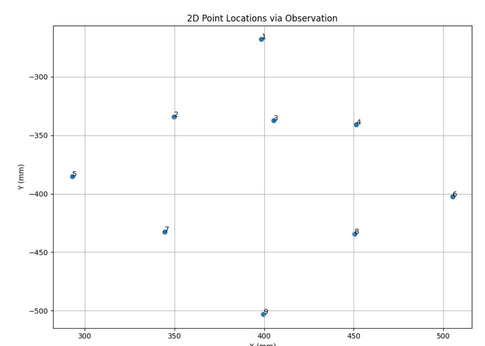

**Figure 3:** 2D Point Location from observations

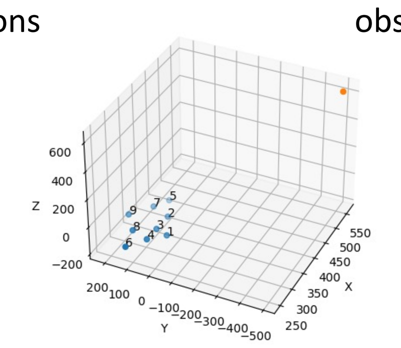

**Figure 4:** 2D Point location and 3D Fluoroscope location

### Point Identification

Using the edge detection algorithm, we were able to define a region of interest to limit the search of the region property's function. This same approach was taken to identify the BB locations within the 3D CT images. The results, when contrasted with the 2D point identification, are more ideal as all the control points were found in a sequential manner and none of the control points were missed. The example image to follow shows a BB located on both the segmented and original CT image slice.

**Figure 5:** BB edge identification and center detection

**Figure 6:** BB edge identification and center detection

## DISCUSSION

### Space Resection

The developed space resection program functioned successfully when considering the criteria of the least squares solution converging and outputting external orientation parameters (EOP). This functionality was tested using given data that had known outputs, showing that the program followed the proper algorithm of collinearity.

In a visual comparison of the observed fluoroscopic points and the points computed via the space resection parameters the differences visible were in the order of a few millimeters. When analyzing the statistical accuracy of the EOP solution, a few problems were noted. The observation residuals were found to be high, with some values as high as 10 mm. This means the observations made likely had an error or were of poor quality. The specific cause has still not been determined; however, some possible causes are blunders or an issue in the accuracy of image information.

### Point Identification

The point detection algorithm was designed to aid in the automation of input control and observations points that are necessary requirements of a functioning space resection program. The results of this program were tested against a manual delineation of point selection and provided similar results.

The group explored a few different approaches of selecting the threshold values such as the well-known Ostu's method and adaptive image thresholding. Ultimately, a manual value was chosen, and the resulting binary image isolated the BBs relatively well. Moreover, the occasional failure to detect a BB was not a significant concern when considering the level of redundancy required to solve for the estimated parameters of the imaging device. Occasionally, the program would detect a feature that was indeed not a BB. To handle this problem, a bounding box was created which limited the search of the program and in such cases, this region had to be adjusted to ensure only BBs were selected.

Another concern was providing the identified BBs with a point identifier to evaluate them in the correct sequence throughout the least squares adjustment. This was not a concern with the CT imagery as each slice dealt with an individual point. There remains a need to correctly position the points collected from both imaging modalities into the space resection program.

## CONCLUSION

The team has developed an innovative program that can autonomously compute the coordinates of fiducial markers from medical DICOM imagery and transmit them to the space resection code to determine the angle of the C-Arm X-ray machine. This cutting-edge solution allows doctors to efficiently obtain the ideal view of the patient's anatomy, thereby reducing the need for the potentially harmful fluoroscopic dye that is typically administered. By enabling smoother and more precise insertion of the prosthetic valve into the aorta, this solution enhances the overall efficiency of the TAVI procedure and lowers its risk, making it a viable option for more patients. In other words, this technology improves the chances of a successful surgery, thereby enhancing the quality of life for numerous patients.

## REFERENCES


[1] A. Holzamer *et al.*, "Multislice computed tomography-based prediction of the implantation plane in transcatheter aortic valve implantation: determination of the line of perpendicularity and the implanter's views," *Eur J Cardiothorac Surg*, vol. 48, no. 6, pp. 879–885; discussion 885-886, Dec. 2015, doi: 10.1093/ejcts/ezv095.

[2] ChatGPT, personal communication, February 15, 2023