# CALIFORNIA STATE SCIENCE FAIR
# 2017 PROJECT SUMMARY

**Name(s)**
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**Project Number**
**S0813**

**Project Title**
## Unlocking History: An Algorithm to Virtually Unfold 3D Computed Tomography Scans of Unopened Historical Documents

**Abstract**

**Objectives/Goals**
In 1926, a trunk filled with 2600 intricately folded and sealed letters from the 17th century was discovered in the Netherlands. Opening the letters risks losing the folding patterns, breaking the seals, and destroying the text. In 2015, researchers at Queen Mary University in London (QMUL) used high-resolution computed tomography (CT) scan machines to image a set of the letters. In my project, I developed an algorithm to virtually unfold the letters and reveal the text inside.

**Methods/Materials**
Working with CT scans of these letters poses significant challenges including touching pages, intricate folding patterns, scatter from lead seals, double-sided text, and low ink-to-paper contrast. To account for this, my software approach combines point, line, and plane detection algorithms. I divide the 3D CT scans generated at QMUL into thousands of 2D cross-sectional images of the letters. I work on each 2D cross-section by creating a point and line detection algorithm. My point detection algorithm identifies candidate points on paper layers in the cross-section. The line detection algorithm then identifies each paper layer by fitting a smooth line along the approximate center. Once line detection is complete on each 2D layer, I proceed to link the lines in the orthogonal direction forming surfaces. Pixels from the 3D data are then extracted into planes using the coordinates from the identified surfaces. The data is plotted as a flat image allowing someone to read the text within.

**Results**
After eight months of concentrated algorithm development and refinement, I was able to extract two nearly complete letters. I verified my algorithm's effectiveness by comparing my extracted images from one letter to photos of the real letter's interior. Finally, I used my algorithm to unfold a letter that still remains closed and sealed in real life.

**Conclusions/Discussion**
The unfolded results I generated using my algorithm achieved my engineering goal and exceeded my initial expectations. Not only was I able to verify my algorithm's effectiveness by testing it on a physically opened letter, but I was also able to virtually open a letter that still remains closed and sealed in real life. The text revealed can now be seen for the first time in over 300 years!

**Summary Statement**
I created an algorithm to virtually unfold 3D computed tomography scans of fragile, 17th century documents without ever physically opening the documents.

**Help Received**
I worked in the MIT Center for Bits and Atoms under the guidance of graduate student Amanda Ghassaei. Although my algorithmic work was independent, my mentor gave advice and helped answer any questions. In addition, the 3D CT data was provided by QMUL with help from the MIT Libraries.