COMPUTATIONAL STRING ART

15781 PROJECT AI : REPRESENTATION AND PROBLEM SOLVING

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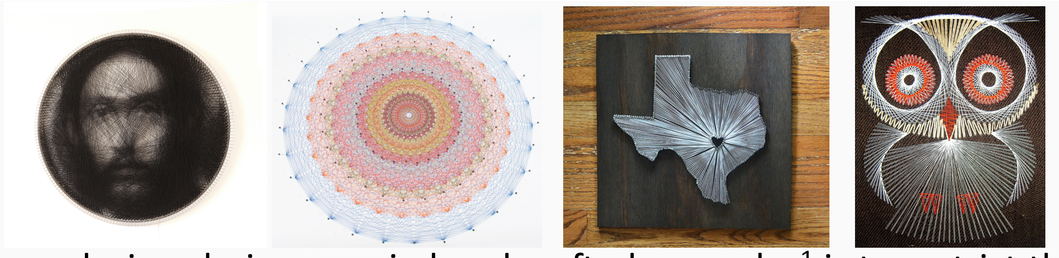
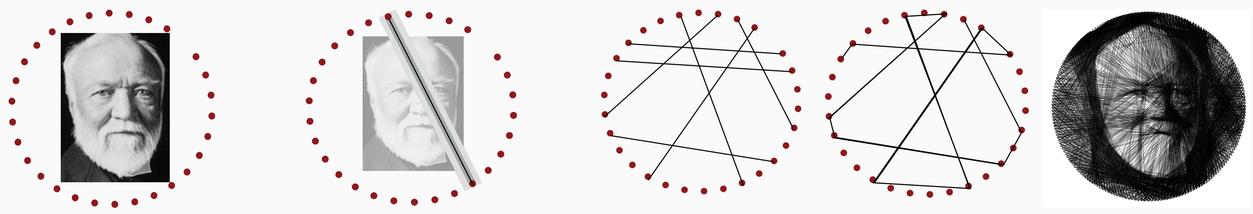
Motivation

String art or pin-thread art is a popular craft that involves winding a string around a set of nails or pins to generate an artifact. An important task in automatic fabrication of such art work involves planning the string layout to achieve a target representation. We explore this planning problem for generating string-art from images automatically.



A common design choice seen in hand crafted examples[1] is to restrict the nail locations rather than having a dense representation. This differentiates the problem setup from coverage planning[2] in robotics and continuous line drawing[3] explored in graphics and non-photorealistic rendering.

Problem Formulation



Input Image and fixed set of *n* nail positions. Image pixels and nails are considered as points in 2D euclidean space.

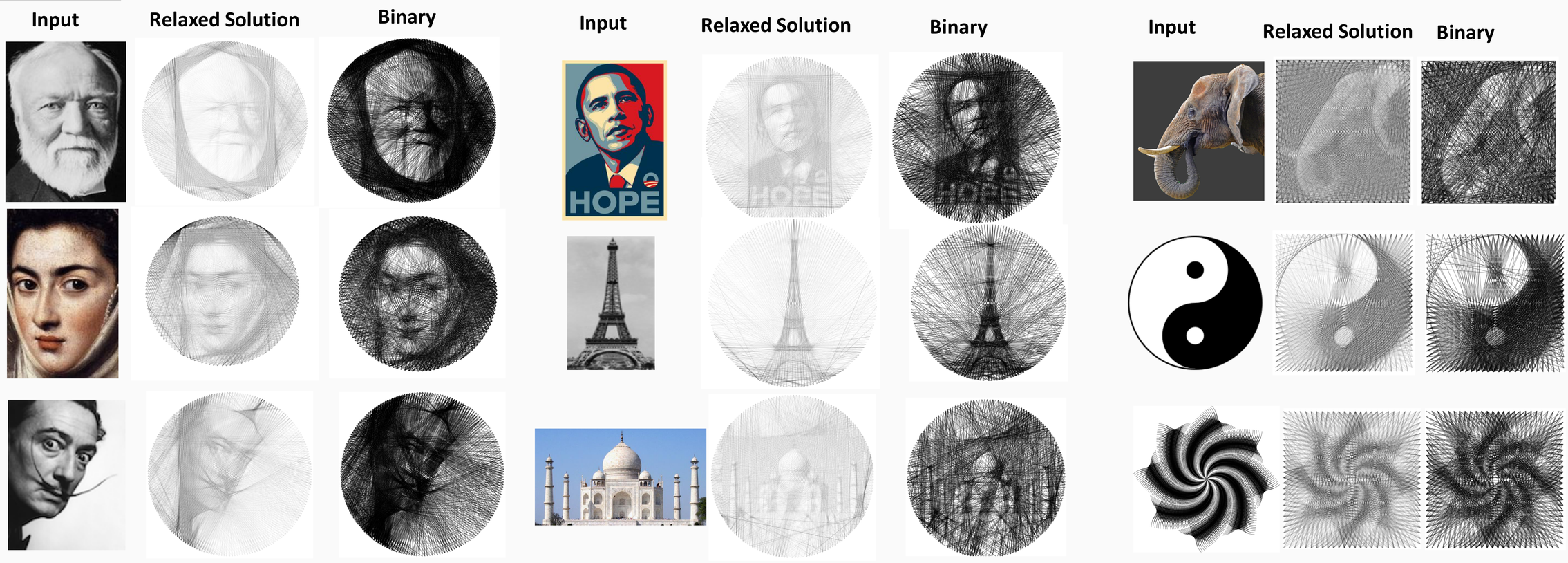
Strings with thickness $2d$ are modelled as line segments .
A pixel is covered by a segment if its distance to the segment is less than d.

Layout planning Identify a sequence of nail positions, such that wrapping strings(segments) along them approximates the input image intensities.
We first identify a subset of segments and then convert it into a single poly-line sequence with a greedy strategy as this is a hard routing problem[4].

String segment selection as an Integer program

Let x be an N-vector that represents all segments, N= $\binom{n}{2}$
B is an M-vector that represents image intensities.
A is an M×N sparse matrix that represents coverage of a pixel i by segment j based on the perpendicular distance $\mathcal{P}(i,j)$ of pixel i from segment j.
A(i,j) = 1- $\mathcal{P}(i,j)/d$ if $\mathcal{P}(i,j) < d$ and 0 otherwise.
We seek a binary vector x, that indicates if a segment j is to be included in the layout such that it best minimizes the L_2 norm of the error in the image representation.
Find $\boldsymbol{x}$ that **minimizes** $\| \boldsymbol{Ax - B} \|_2$, $\boldsymbol{x} \in \{\mathbf{0}, \mathbf{1}\}$
We relax the binary constraints and solve the quadratic least squares with L1 regularization. A suitable threshold to binarize the solution is computed by line search.
Results generated with d=0.5 and $n \approx 250$ are shown below. Segment value is mapped to its opacity.

Results



Future work

- Nail positions optimization for better representation of the input image.
- Explore the role of perceptual effects in visualizing string patterns.
- Incorporate fabrication constraints in the planning stage.

References

1. First example image from Artist Petros Vrellis' experimental knitting.
2. Enric Galceran, Marc Carreras, A survey on coverage path planning for robotics, Robotics and Autonomous Systems, Volume 61, Issue 12, December 2013
3. Forrester Cole, Aleksey Golovinskiy, Alex Limpaecher, Heather Stoddart Barros, Adam Finkelstein, Thomas Funkhouser, and Szymon Rusinkiewicz. 2012. Where do people draw lines?. *Commun. ACM* 55, 1 (January 2012)
4. Eiselt, Horst A., Michel Gendreau, and Gilbert Laporte. "Arc routing problems, part II: The rural postman problem." *Operations research* 43.3 (1995): 399-414.