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.

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 Layout planning Identify a sequence of 2d lines are modeled as nail positions, such that wrapping line segments. A pixel is covered by a segment if its distance to the segment is less than $d$.

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 $M\times N$ sparse matrix that represents coverage of a pixel $i$ by segment $j$ based on the perpendicular distance $P(i, j)$ of pixel $i$ from segment $j$. $A(i, j) = 1 - P(i, j)/d$ if $P(i, j) < d$ 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 $x$ that minimizes $\|Ax - B\|_2$, $x \in \{0, 1\}$ We relax the binary constraints and solve the quadratic least squares with $L_1$ 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