Computational LEGO® Design

Student: YUAN Shaoxuan Supervisor: Prof. Chi-Wing FU, Philip

Introduction

LEGO model can display many shapes of different objects, which is a great decoration. However, to construct such a model, LEGO designers have to spend significant amount of time and energy. To improve the construction efficiency, we aim to use a computational strategy to generate LEGO models according to 2D shapes. In this project, we will show the construction and optimization method.

Related Work

In recent years, many work related to LEGO construction have been explored. Zhou et al. [1] show a computational method to create LEGO sketch art. What is more, Luo et al. [2] and Liu et al. [3] present a process to analyse the stabillity of LEGO building. Based on these researches, we will come up a strategy to generate stable LEGO models using selected bricks.

Task Definition & Methods

Task definition: Our aim is to using a set of LEGO bricks to match the shapes in the input images; see figure below.

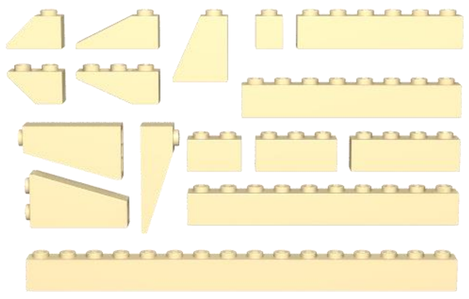


Figure: brick set

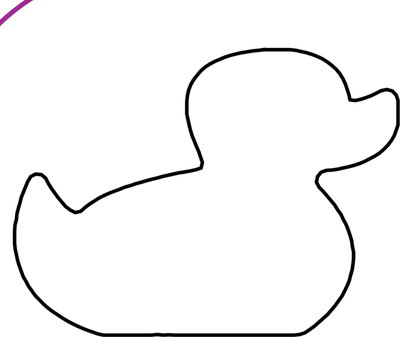
Methodology: Our method includes two main steps:

Construction

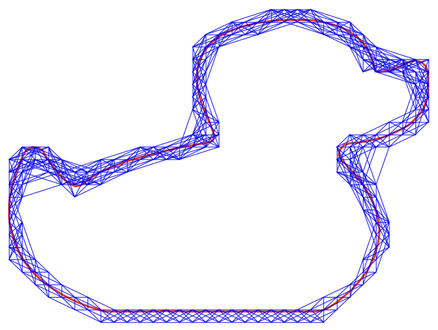
- *Graph creating*
- *Graph optimization*
- *Bricks filling*

Optimization & Analysis

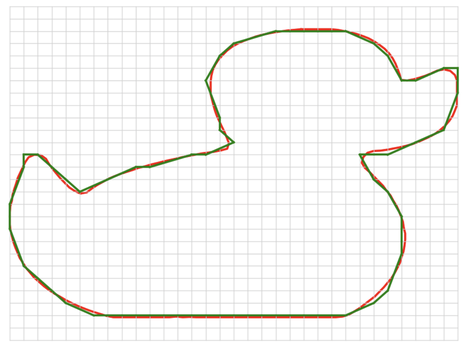
- *Connectivity optimization*
- *Stability analysis*



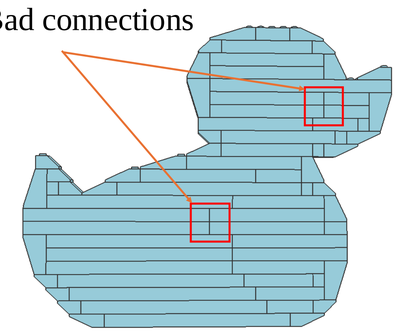
input image



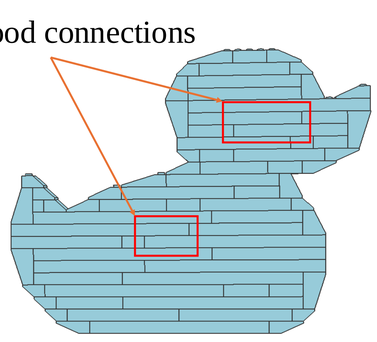
candidate edges along the contour



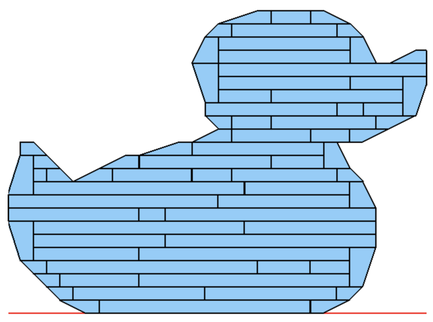
contour polygon obtained by graph optimization



the model after filling with a greedy algorithm



the model after connectivity optimization



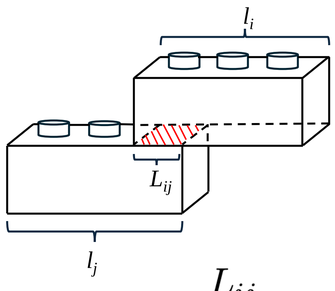
physical stability analysis and visualization

Optimization Methods

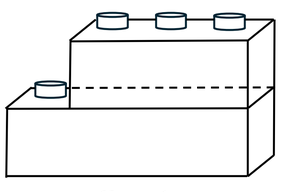
Graph Optimization: In this step, we follow the strategy of Zhou et al [1]. We use the objective function below to measure the effect of fitting.

$$W = w_d L_d + w_v L_v + w_s L_s$$

Connectivity Optimization: We aim to use less bricks to generate more connections. We associate each brick with a binary variable x_i. We will consider a structure consisting of two bricks; see left structure below. And we prefer interlaced structure and try to avoid aligned structures; see middle and right structures below.

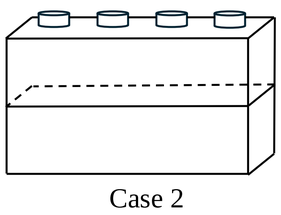


$$\mathcal{E}_{ij} = x_i x_j \frac{L_{ij}}{l_i + l_j}$$



Case 1

$$T_{ij} = x_i x_j$$



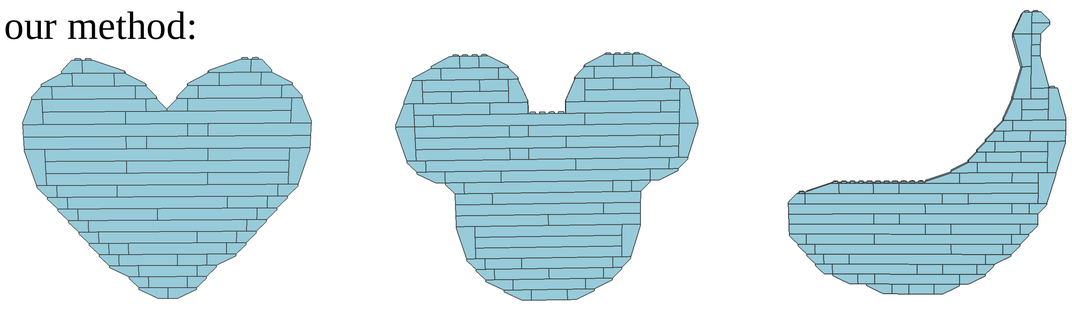
Case 2

$$T_{ij} = 2x_i x_j$$

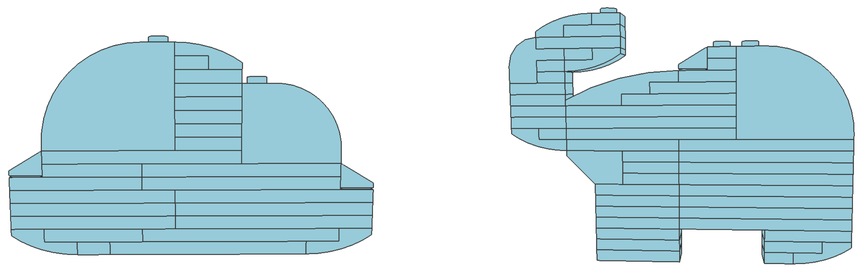
$$\mathcal{C} = \sum_{i<j} \mathcal{E}_{ij} + \sum_{i<j} T_{ij}$$

Results & Extension

Results: Below are some LEGO models generated and optimizated by our method:



Extension: Based on previous work, we have enlarged our brick set by adding curved bricks to generate better models. There are some preliminary results; see figure below. In the future, we will consider constructing LEGO models in smaller sizes and multi-orientations.



Reference

[1] ZHOU, M., GE, J., XU, H., AND FU, C.-W. Computational design of lego sketch art. *ACM Transactions on Graphics (TOG) 42*, 6 (2023), 1-15.
[2] LUO, S.-J., YUE, Y., HUANG, C.-K., CHUNG, Y.-H., IMAI, S., NISHITA, T., AND CHEN, B.-Y. Legolization: Optimizing lego designs. *ACM Transactions on Graphics (TOG) 34*, 6 (2015), 1-12.
[3] LIU, R., DENG, K., WANG, Z., AND LIU, C. Stablelego: Stability analysis of block stacking assembly. *arXiv preprint arXiv:2402.10711* (2024).