# From CAD Models to Toy Brick Sculptures: A 3D Block Printer

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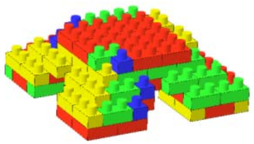

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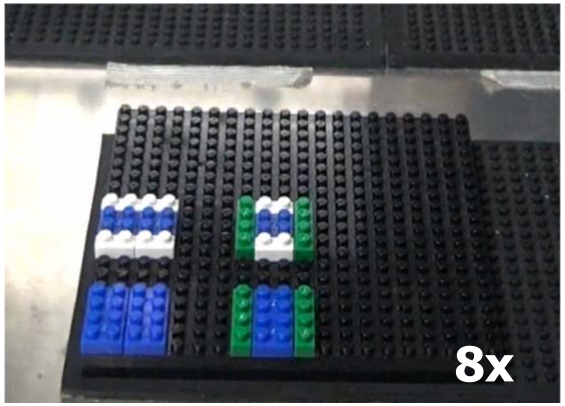


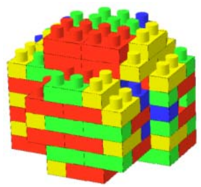

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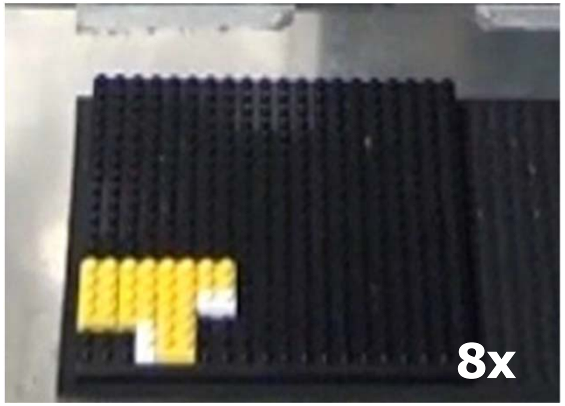


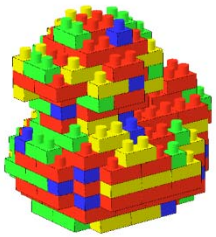

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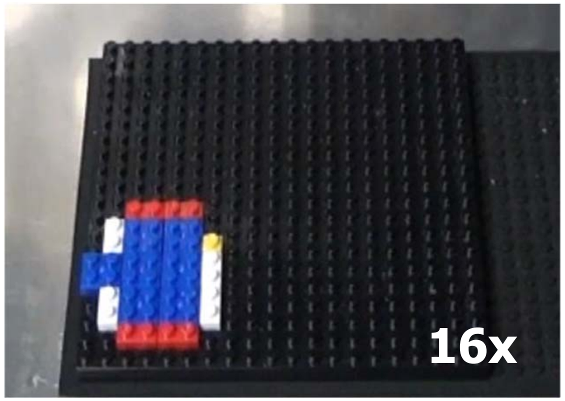


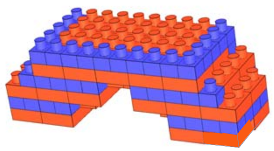

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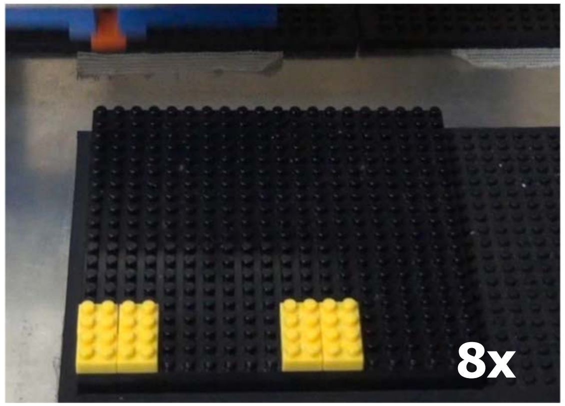
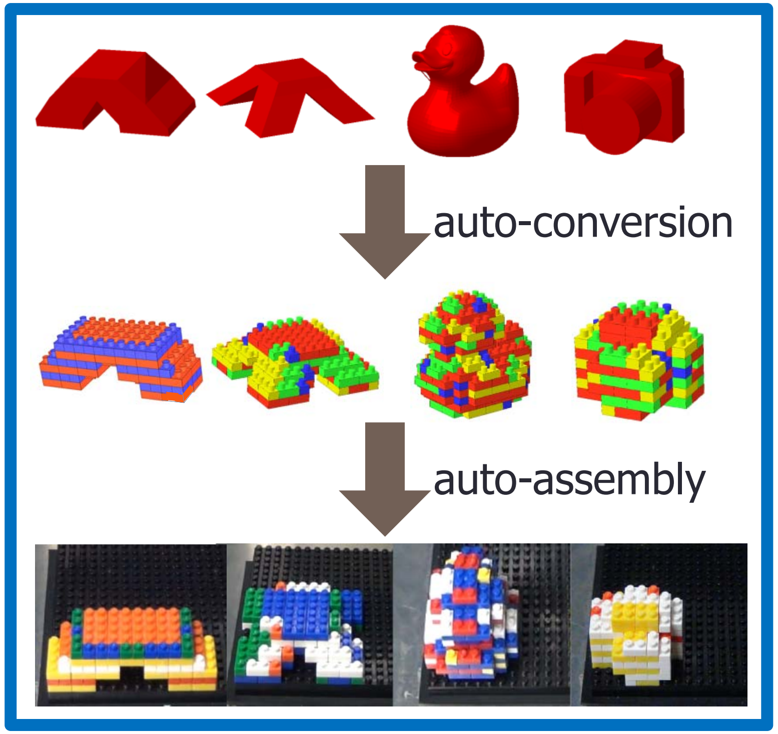


# Overview

- A robotic 3D printer that uses toy bricks as digital material is presented
- A 3D CAD model is automatically converted into a block model consisting of primitive blocks
- An assembly plan of the block model is automatically generated
- A toy brick sculpture is automatically assembled layer by layer according to the plan by a robot



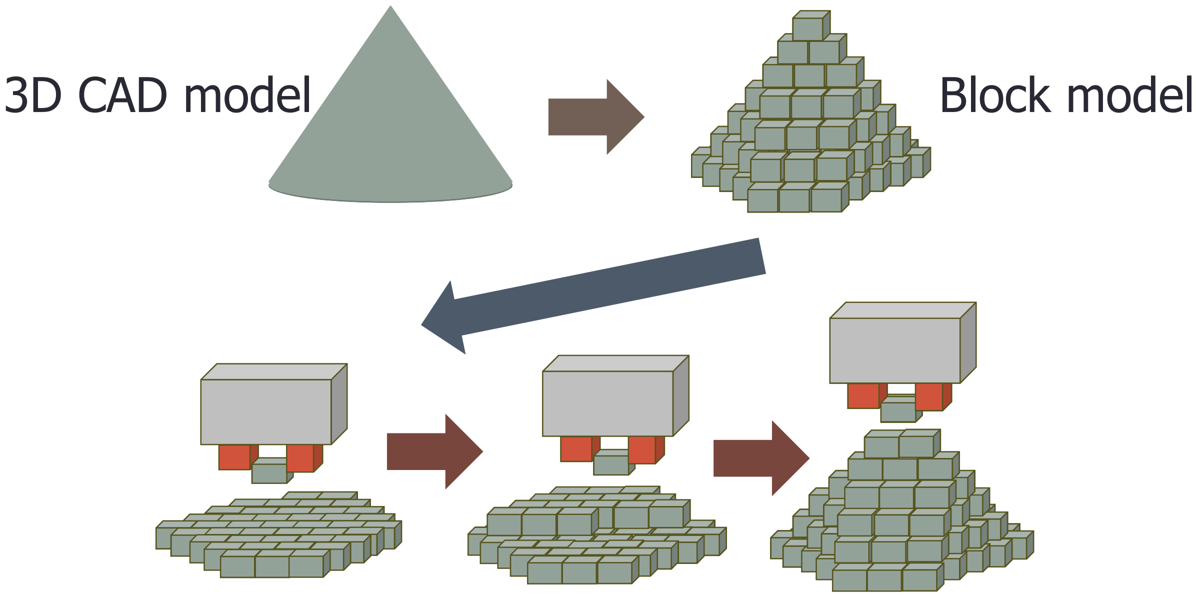

Supported by JSPS KAKANHI JP15H03944

# Background

- Digital materials including LEGO-like blocks can be used for additive manufacturing
  - “Voxel Printing” [Hiller and Lipson 2009]
  - Perfect repeatability
  - Multiple materials
  - Smart voxels
  - …

# Objective

- To develop a robot system that assembles LEGO-like toy blocks to produce brick sculptures



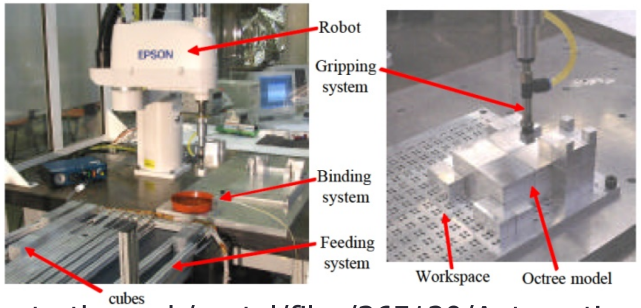
Layer-by-layer assembly of brick sculpture

# Related works

- A “VoxJet” Printer with spherical voxels [Hiller and Lipson 2009]

https://sites.google.com/site/jonhiller/hardware/rapid-assemblers/voxjet

- A SCARA robot that assembles cubes with gluing [Medellin et al. 2010]



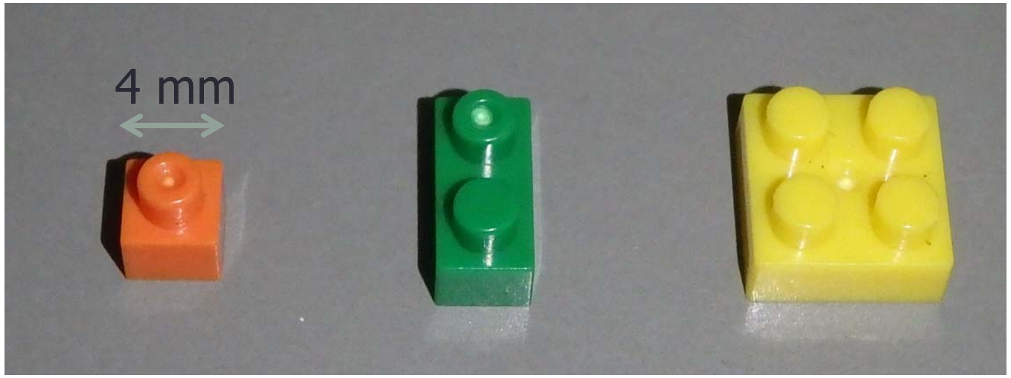

https://pure.strath.ac.uk/portal/files/365120/Automatic_generation_of_robot_and_manual_assembly_plans.pdf

- A parallel robot that assembles truncated octahedra with magnetic connectors (“Kelvin blocks”) [Sekijima et al. 2015]
- …

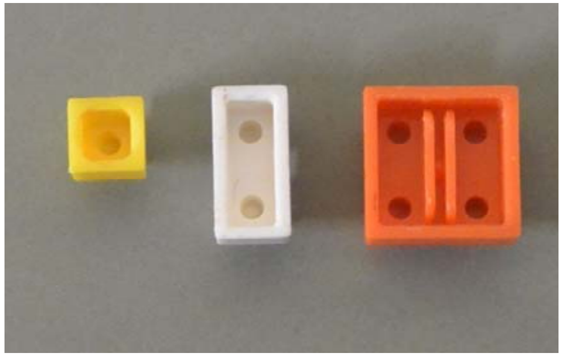
http://fab.sfc.keio.ac.jp/?projects=kelvin-block

# Building blocks

- “nanoblock” by Kawada

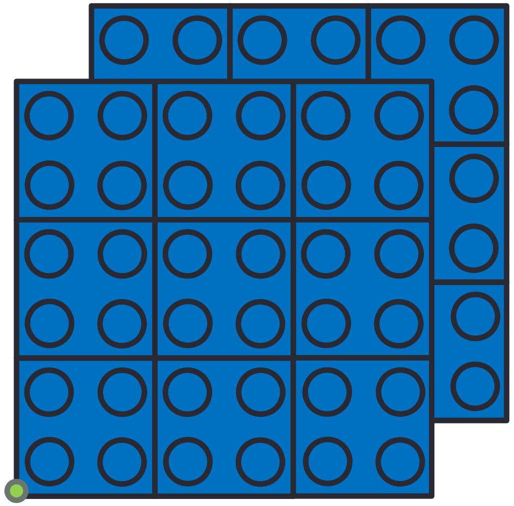



1x1 2x1 2x2



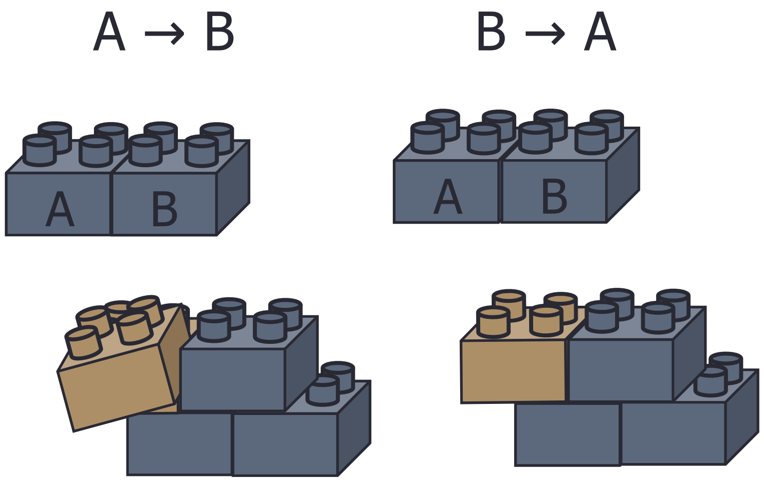
# Conversion from a 3D CAD model to a block model

- An automatic conversion method [Kozaki et al. 2016] is adopted
  - A 3D CAD model in OFF (Object File Format) is converted to unit voxels with edge length ratio of 4:4:3
  - Then the voxels are replaced by the primitive blocks so that the number of blocks are reduced using simulated annealing
  - The reference point for the replacement is shifted one unit in column and row directions for each layer to strengthen the assembled structure



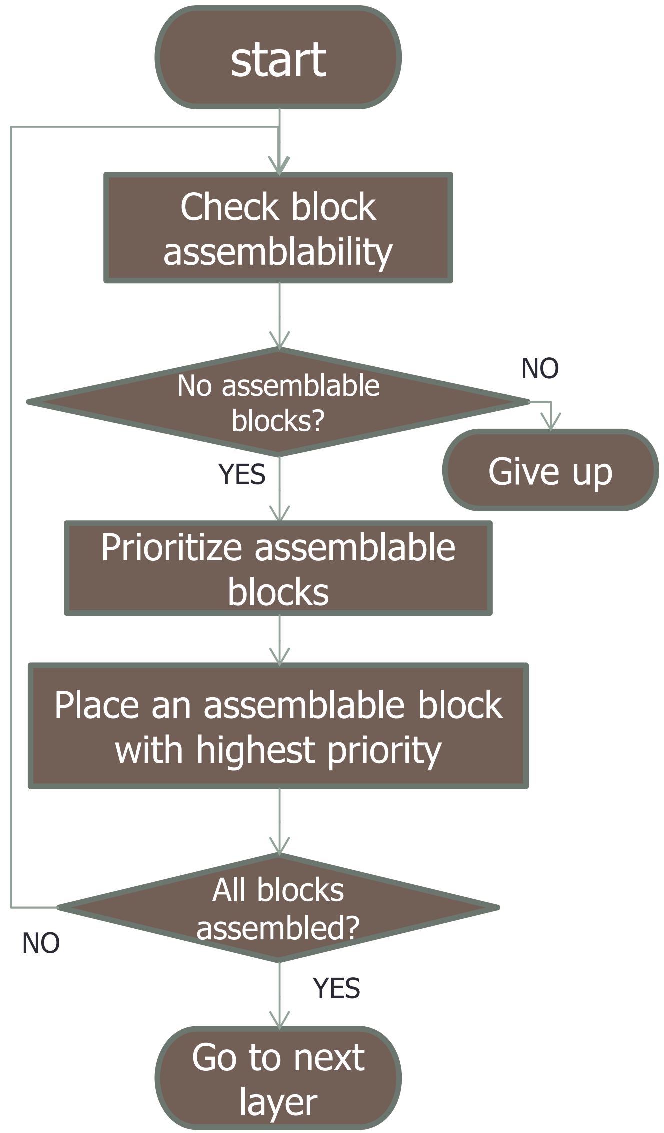
# Assembly planning (1/2)

- Assembly success depends on the order of block placement

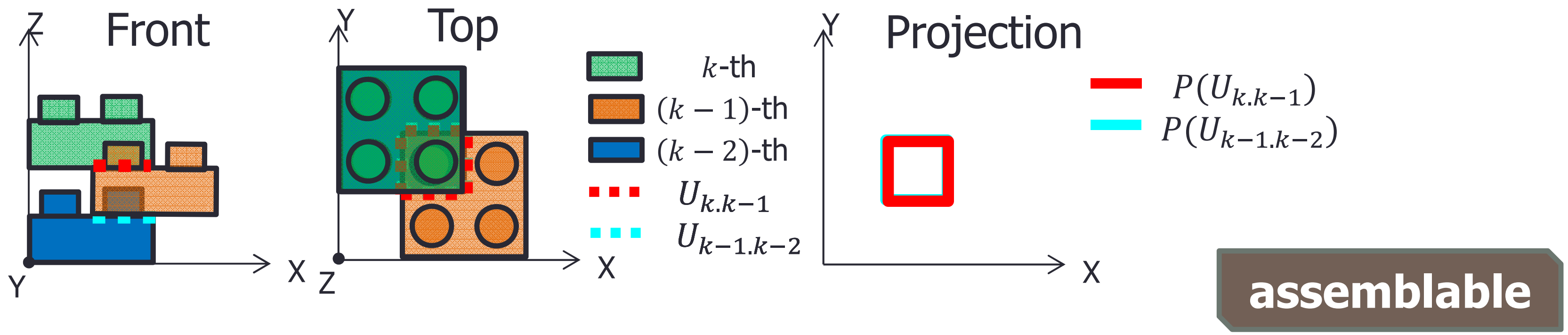


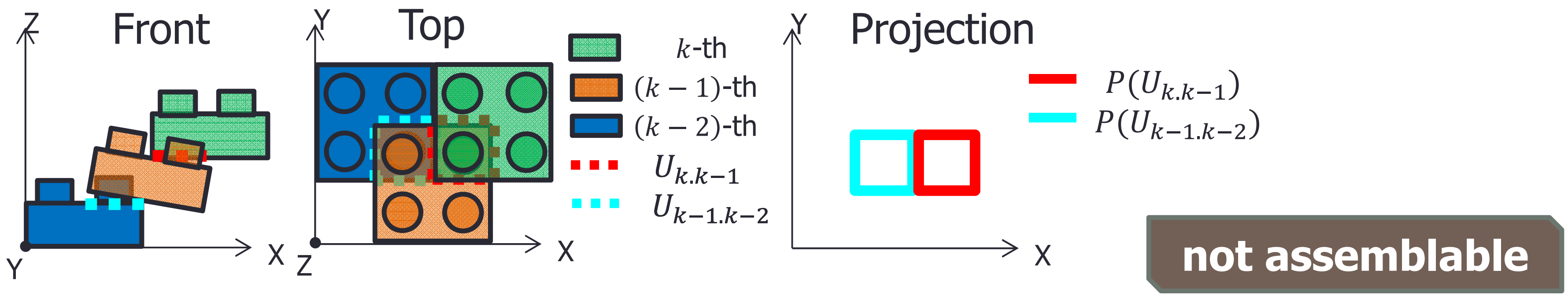
# Assembly planning (2/2)

- Assumption
  - Bottom-to-top, layer-by-layer assembly
  - Block placement by vertical insertion
- Assembly planning requires:
  - Block assemblability check
  - In-layer block placement ordering

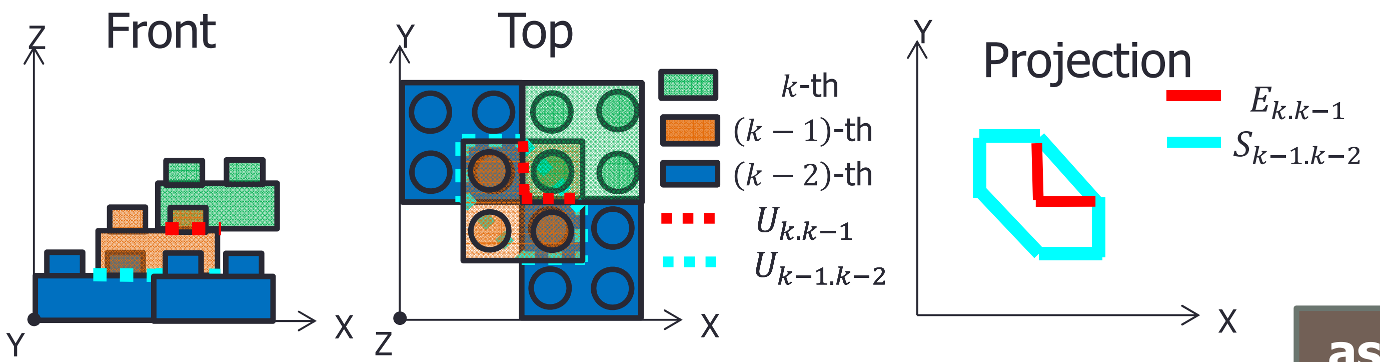


# Block assemblability check: Contact region inclusion

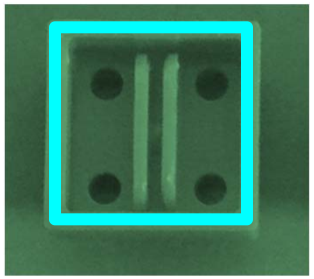


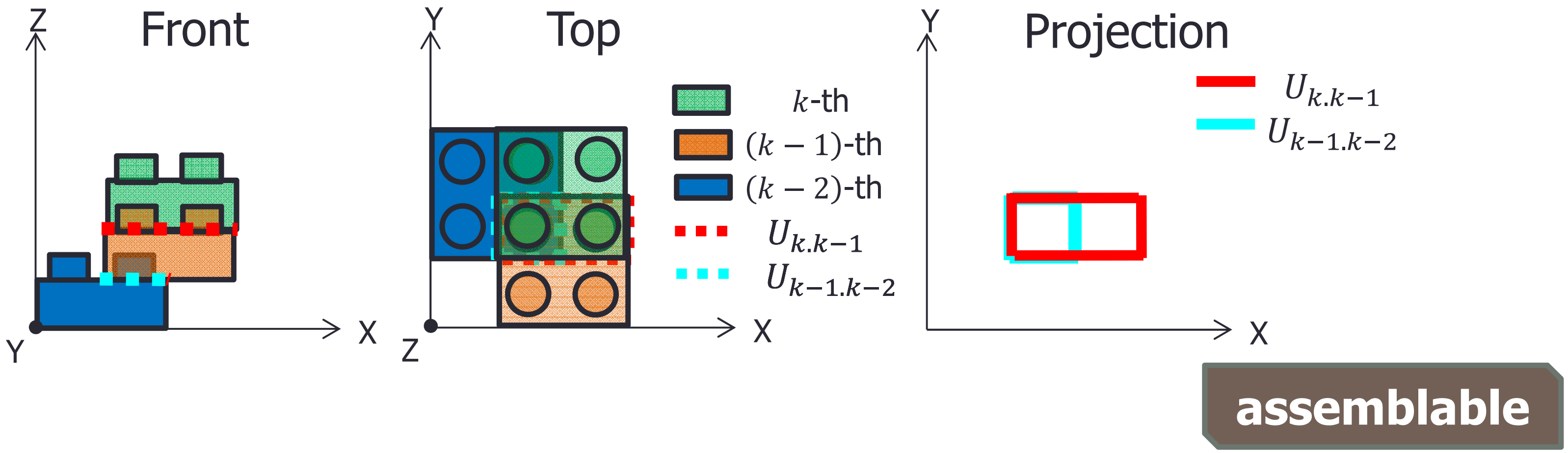
# Block assemblability check: Contact edge inclusion



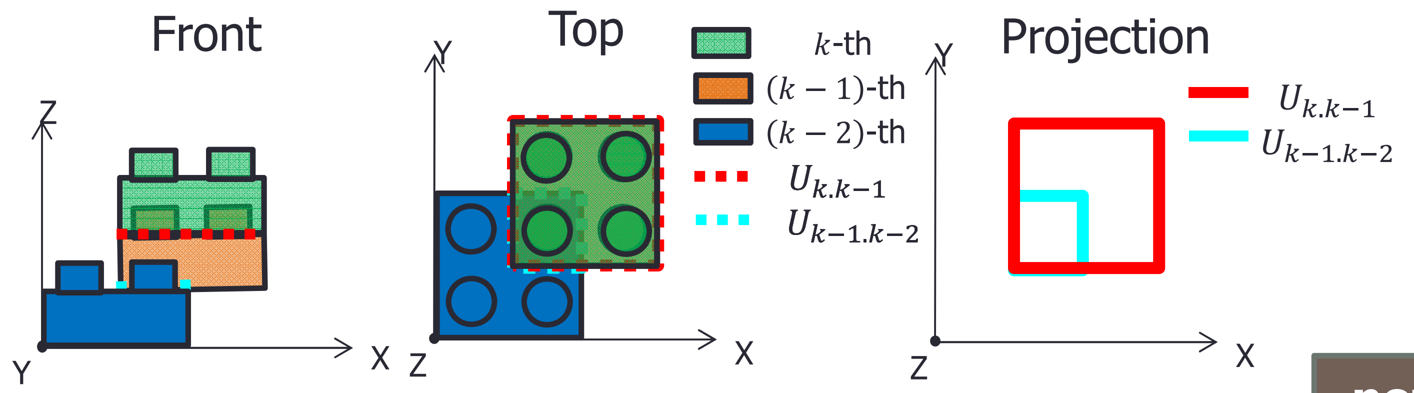

**assemblable**



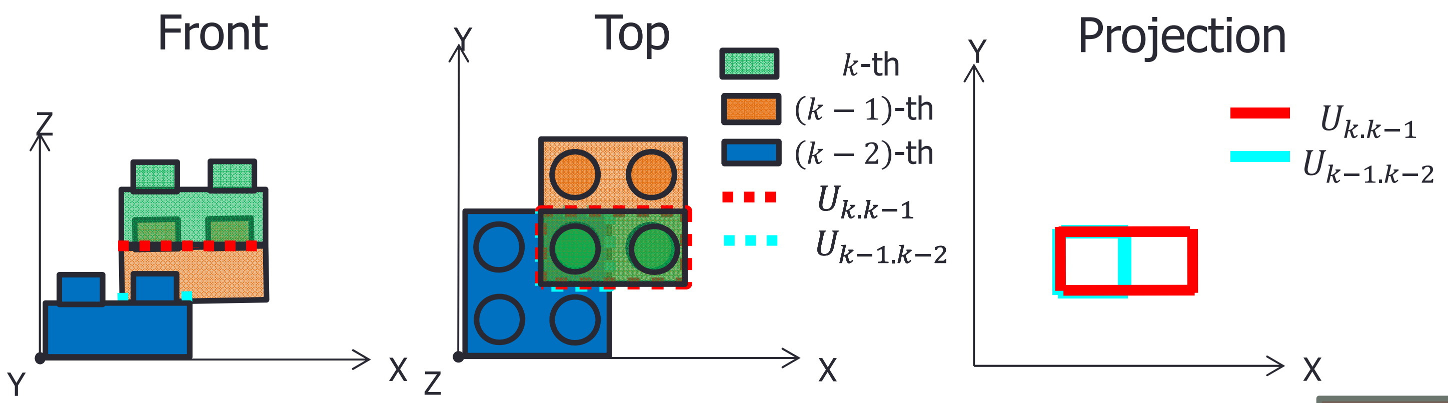
# Block assemblability check: Multi-stud connection (1/2)



# Block assemblability check: Multi-stud connection (2/2)

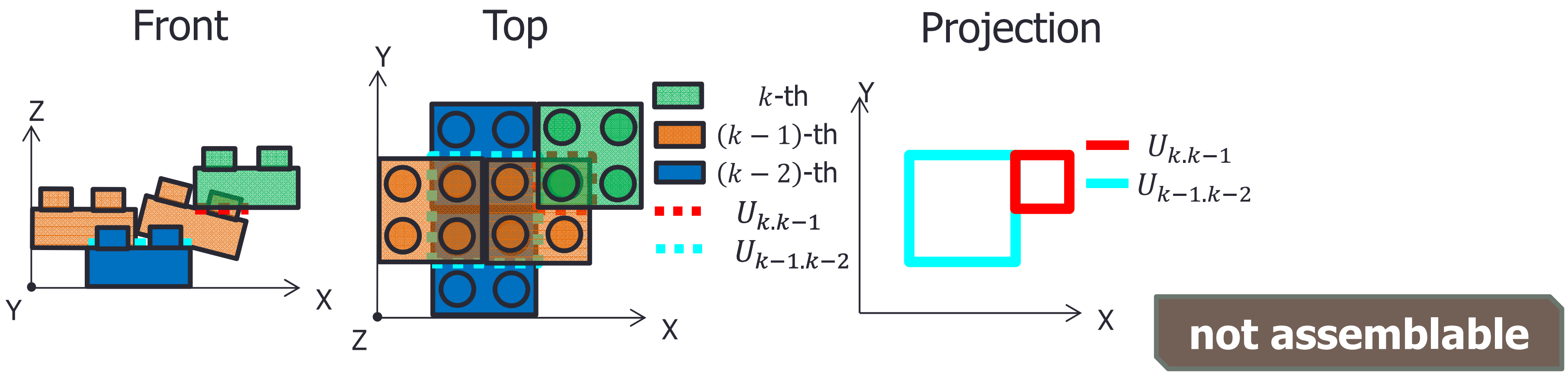


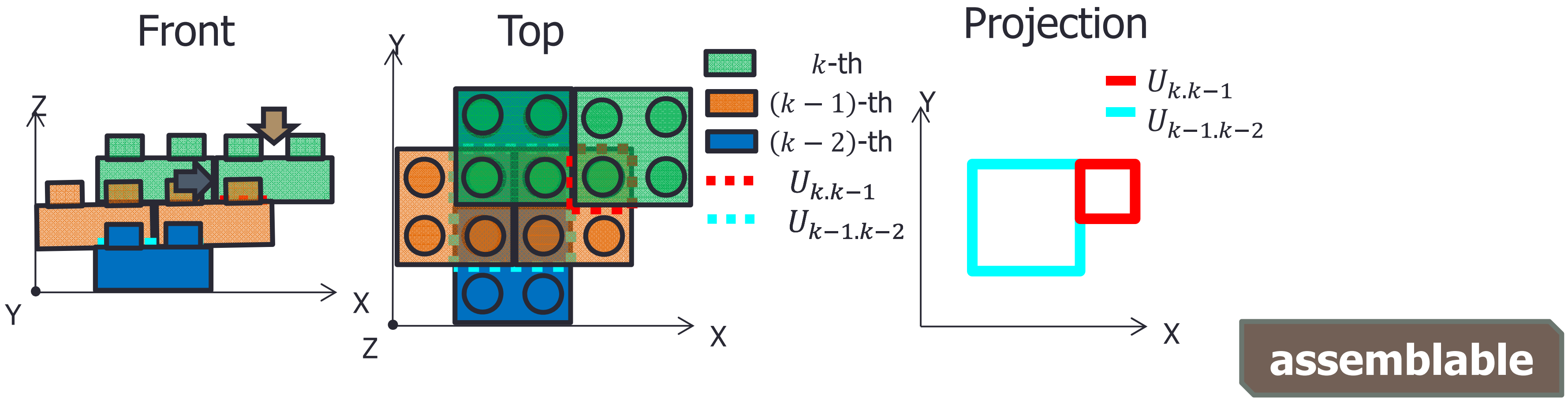

**not assemblable**




**not assemblable**

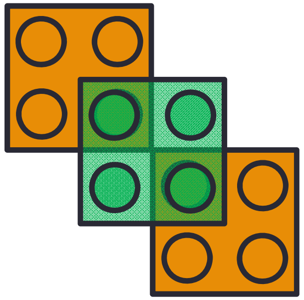
# Change of block assemblability



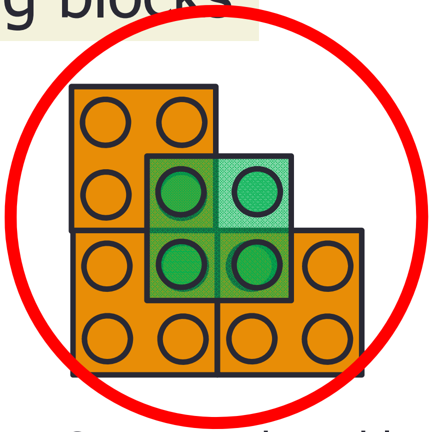



# Block placement ordering: Prioritization

## # of connecting blocks

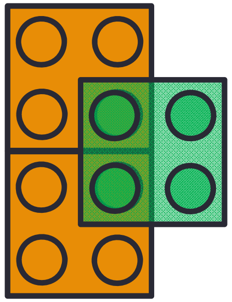


Connects two blocks

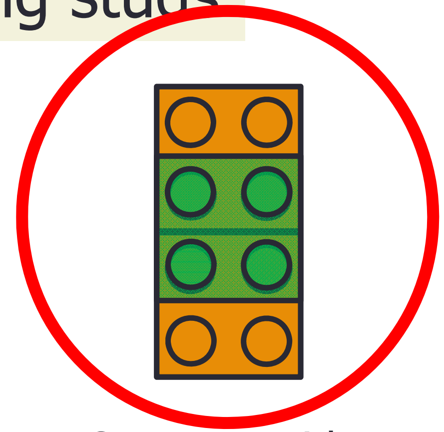


Connects three blocks

## # of connecting studs

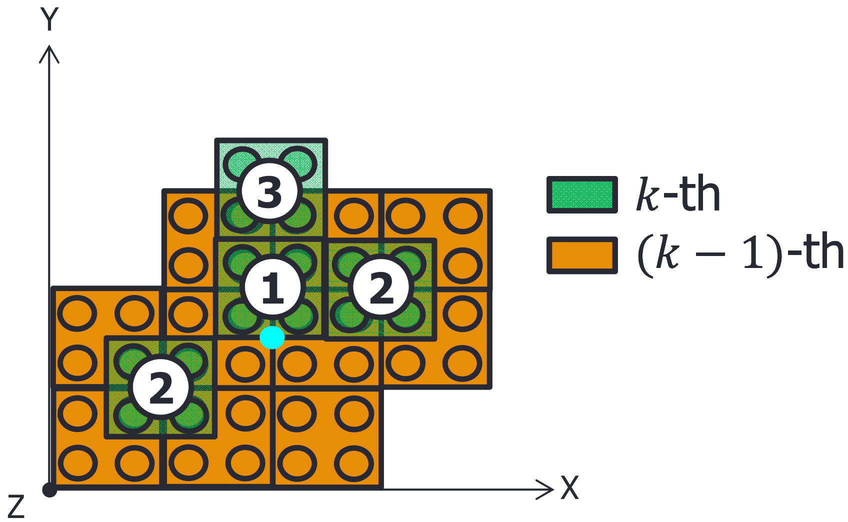


Connects with two studs

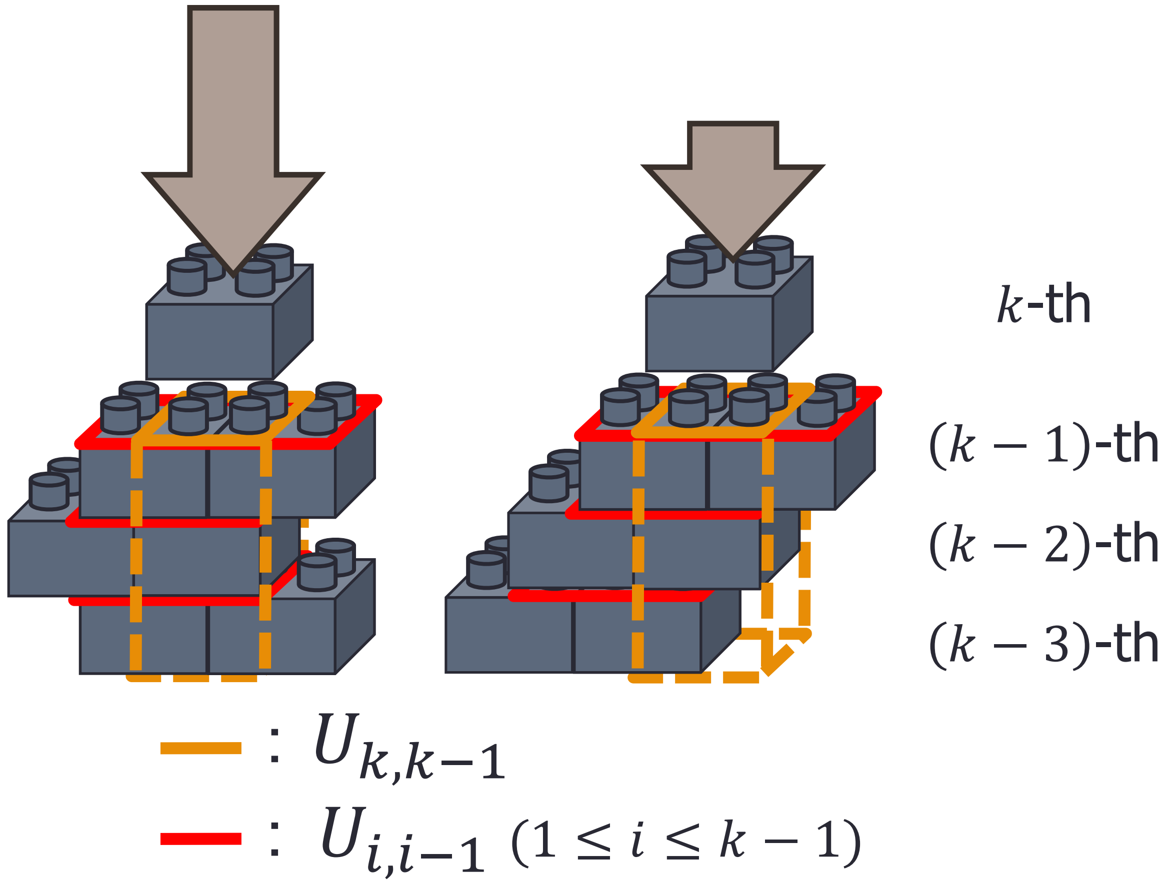


Connects with four studs

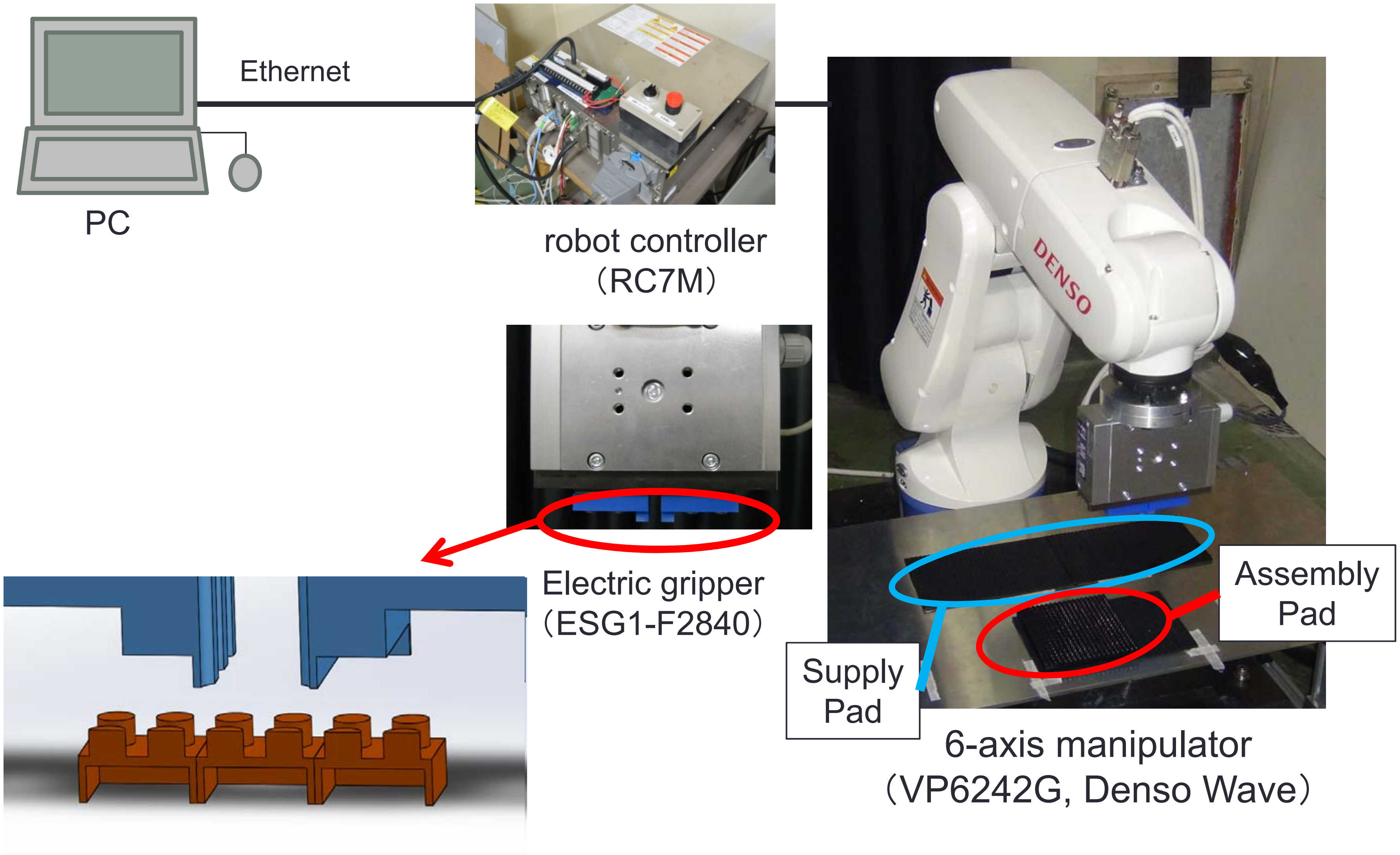
## Inter-centroid distance



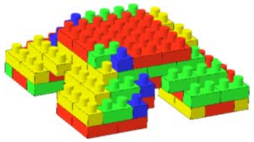
# Force control in assembly



# Experimental Setup



# Assembly experiments



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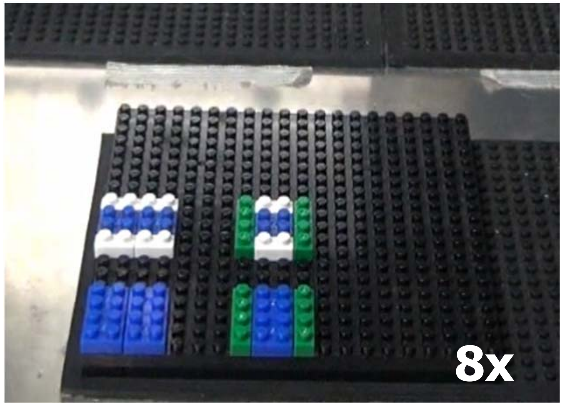


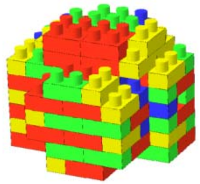

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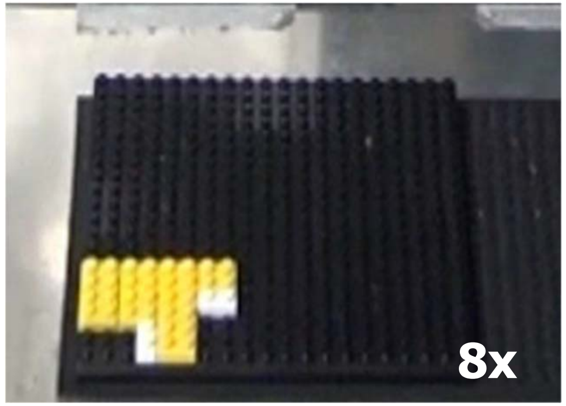


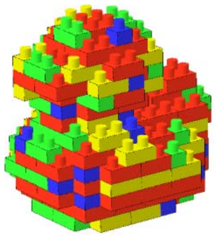

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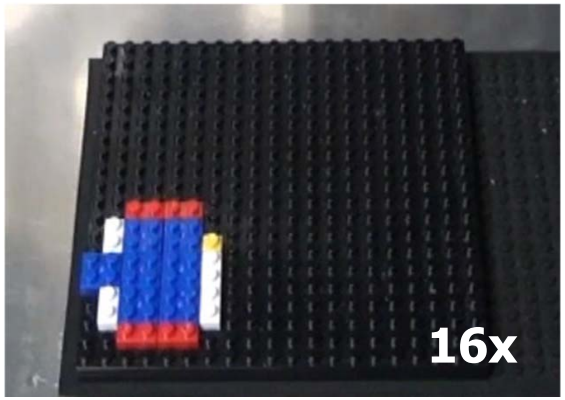


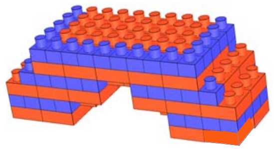

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