# Designing precrease patterns for clean folding of tessellations and boxes

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# **Motivation**



# Assumptions

- no cutting or glue
- only manual folding, but...
  - bone folder and similar tools are OK
  - ruler for dividing paper edge into N-ths is OK

### **Crease Pattern vs Pre-crease Pattern**





# **Pre-crease Pattern (PCP) is ambigous**



#### **5** Triangle Twist

### **Basic vs clean PCP**





### **CP vs clean PCP**





### PCP still has extra creases, but hidden





### **Clean PCP**

- just one out of many possibilities
- affects the collapse (unlike CP)
- balance between perfection and practicality

# A simple case



# What is visible?





# **Eliminating some creases**





# **Clean version**



# **Clover Folding** — in practice

- simple case
  - creases go all-through the sheet
  - no need to construct references in multiple steps
- using pinches to mark distances
- collapse of cleaned-up CP is harder...
- ...and takes more time

### More difficult case



# Starting with "perfect" PCP







17 Start with perfect PCP. Factorize the size of underlying grid. Here:  $24 = 3 \times 2 \times 2 \times 2$ 



**18** First-generation horizontal creases. Look for simple divisions (here: 24 grid  $\Rightarrow$  8/24 = 1/3)



Second-generation creases: what can be easily constructed from what is already there?



20 Continue constructing creases. Mark pinches for use later. Some crease parts are not in original CP.



Fourth-generation horizontal creases



22 Copy fragment of crease from above using mirroring



**23** First-generation vertical creases. Use same construction methods as for horizontal creases.



24 Second-generation creases and pinches for use in later steps



**25 Third-generation vertical creases** 



**26** Fourth-generation creases. Again, we crease some fragments not creased in perfect CPC.



7 Connect the dots to crease diagonals



28 Crease between two points (2 grid diagonals) and elongate to 3 grid diagonals



Now, we've built references that allow us to crease the last two diagonal fragments



Finished "clean but practical" PCP

# **Clean version**



### **Framed Heart** — in practice

- more complex case
  - some creases end in the middle of the paper
  - some elements can be constructed only after others
- using edges of paper (box vs tessellation)
- precrease contains creases which are flat in folded model (but hidden)
- perfectly clean precrease not practical to fold
- clean precrease somewhat tedious to fold
- larger molecule benefits more from clean-up

# **Common techniques**

- greedy algorithm: at each step see what can be constructed from what is already there
- all-through creases, short creases, pinches
- dividing a segment into 2 or into 3
- mark crease and elongate later
- copying a segment
  - parallel
  - to an intersecting crease
- using paper edges (if available)
- mostly same tricks for square and hex grid

# Challenges

- loss of precision without the grid
- precision depends on precision of paper cut
- errors can accumulate or cancel out
- not all papers allow bending without creasing
- design and folding take more time
- balance between clean fold and practicality
  - sometimes not worth the fuss
  - folding should still be fun



# Thank you

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