Self-assembling tilings: practical advances in theory

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TAGp2010

DNA self-assembly

- Synthesis of nano-things

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- Try to come up with a bunch of DNA-complexes (bricks)...
- ...which self-assemble into what you want
- Starting with avogadrian numbers of bricks... (DNA sequence synthesis)
- ...end up with (at least some copies of) the shapes you want

Introduction

- A theoretical model of self-assembly
- Simple model
- Not tied to dna/proteins
- Good match nonetheless
- Good for computer science: massive parallelism (shape synthesis == computation)
- We'll see steps to introduce "some" realism

Don't know much about Geography

- No genomics
- No chemistry
- Real problems
- Theoretical tools

Outline

1. Elective Affinities
   - Self-assembling Tilings
2. The Importance of Being Earnest
   - Eliminating errors
3. Brevity is...
   - Towards a programming language

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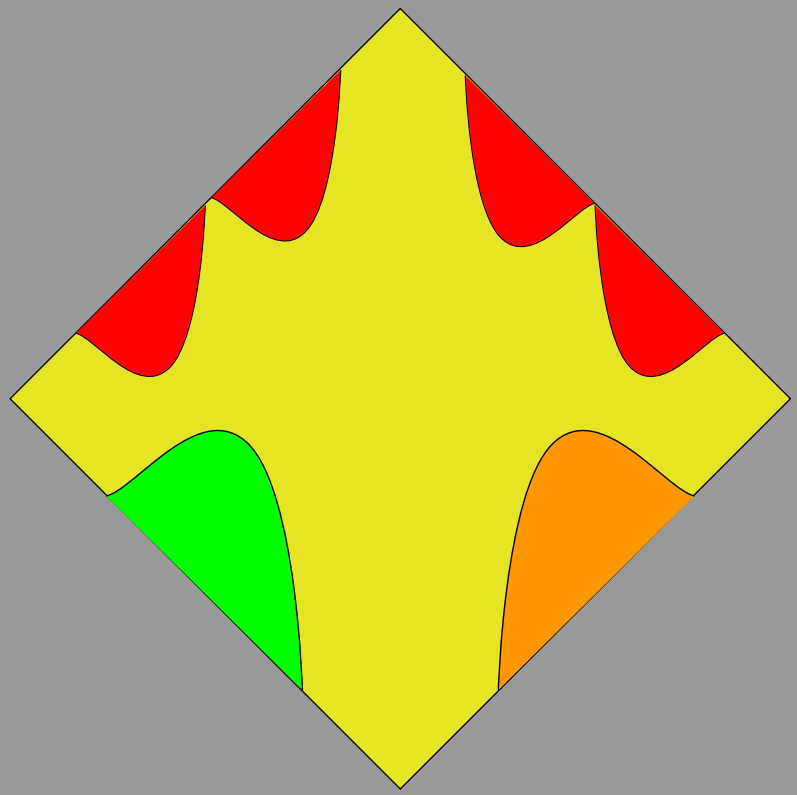
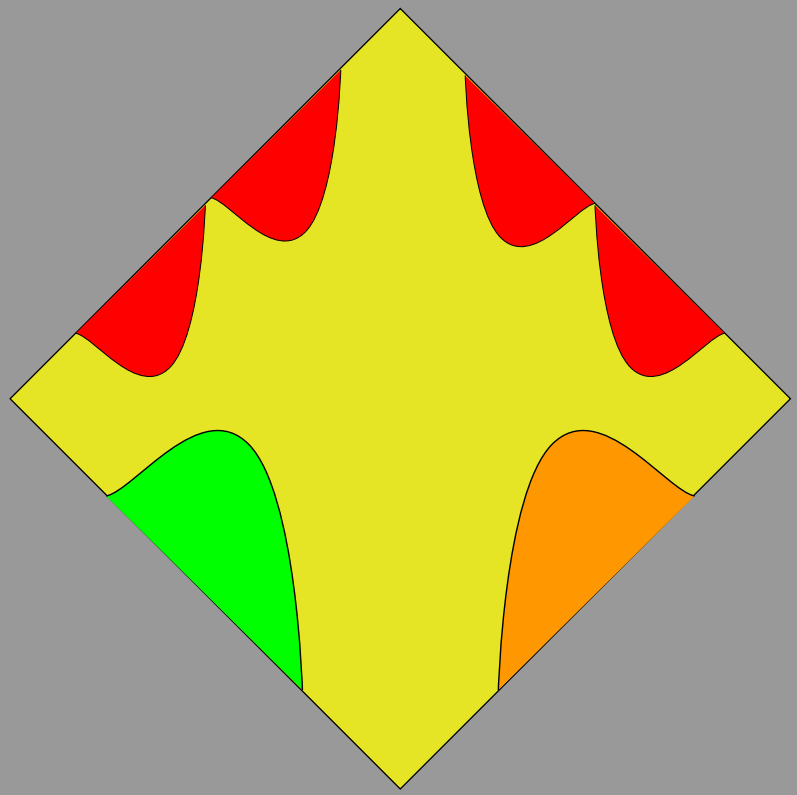
Self-Assembling Tiles

- A set of square DNA dominoes,



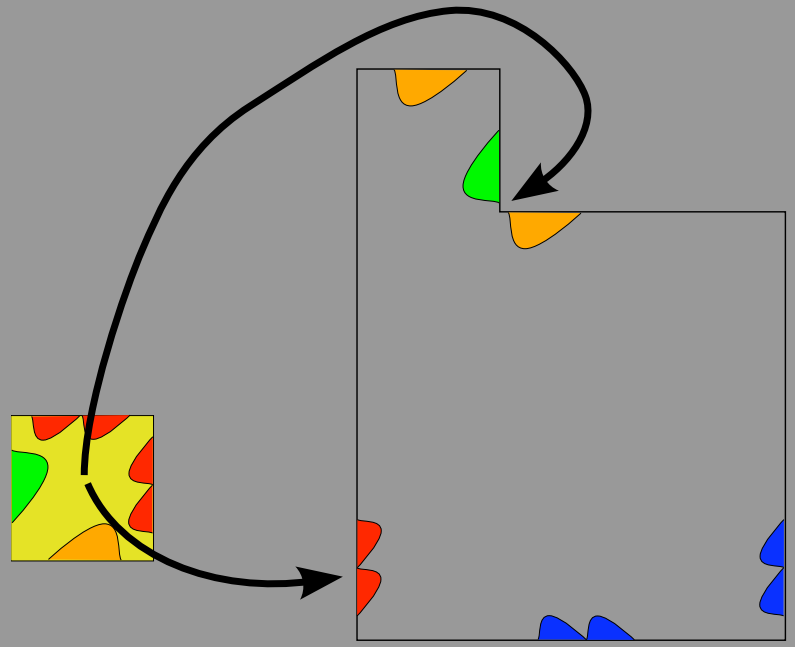
Self-Assembling Tiles

- A set of Wang tiles,



Self-Assembling Tiles

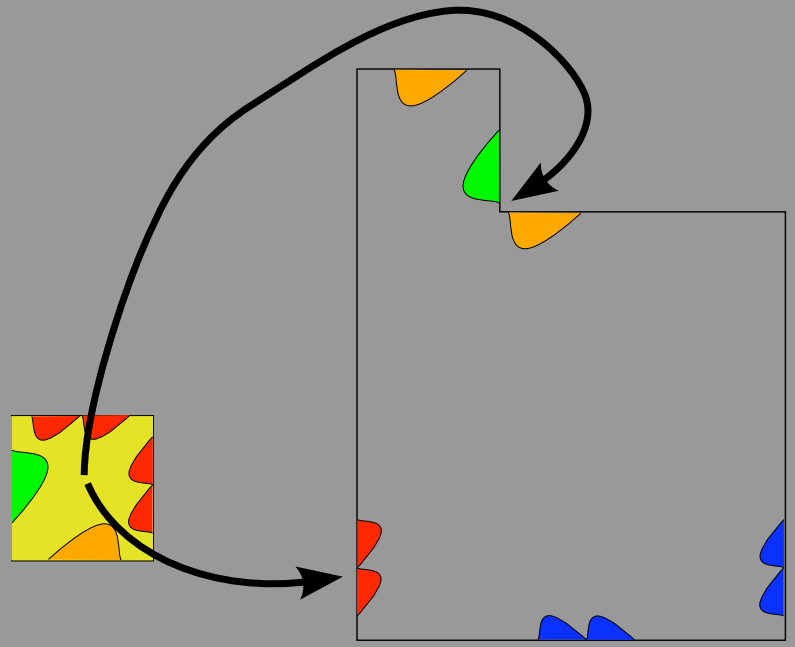
- A set of Wang tiles,
- Each side has a DNA sequence.



Example at $T = 2$

Self-Assembling Tiles

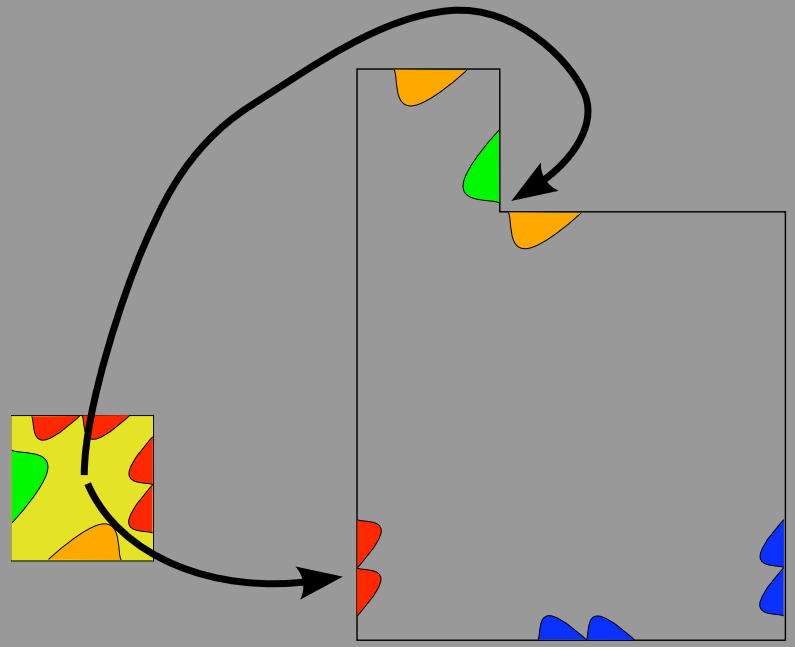
- A set of Wang tiles,
- Each side has a color and a strength (= glue).



Example at $T = 2$

Self-Assembling Tiles

- A set of Wang tiles,
- Each side has a color and a strength (= glue).
- To add a tile, complementary bases attract each other



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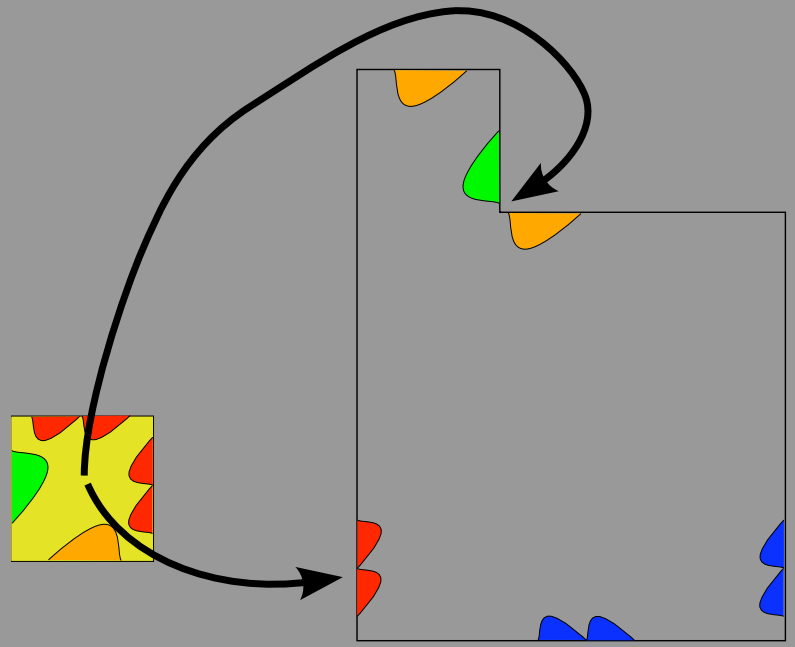
- Each side has a color and a strength (= glue).
- To add a tile, it must stick with strength at least T: the *temperature* (generally, 2...)



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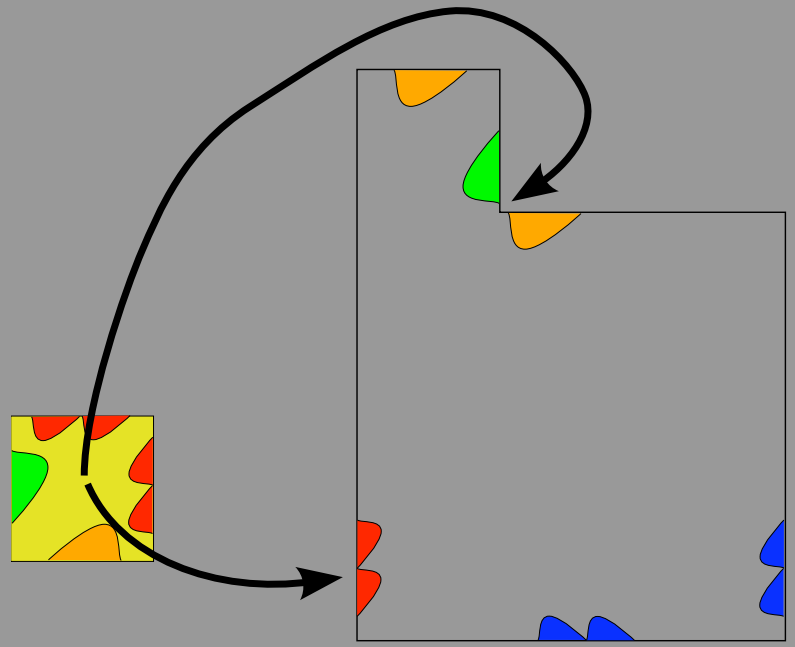

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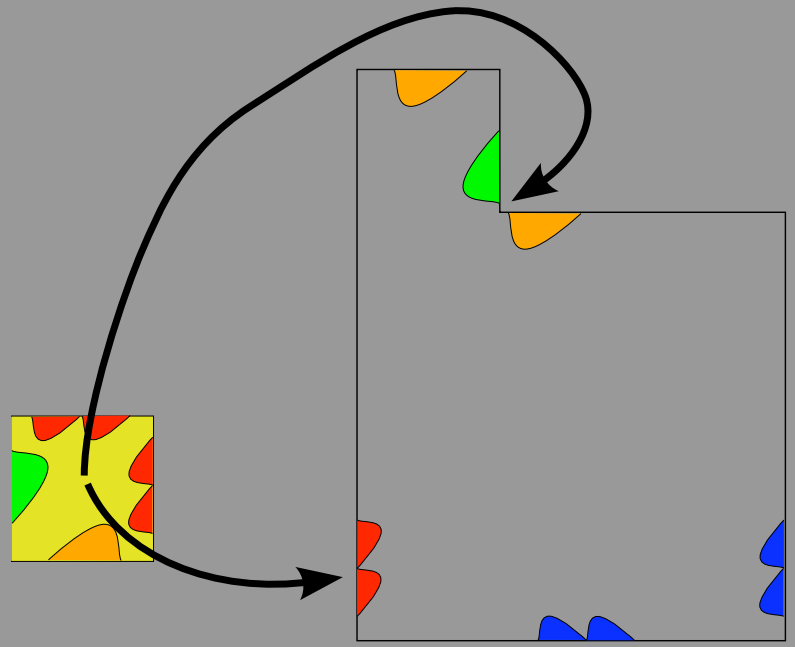
Self-Assembling Tiles

- A set of Wang tiles,
- Each side has a color and a strength (= glue).
- To add a tile, it must stick with strength at least T: the *temperature* (generally, 2...)
- Non-deterministic system
- Parallelism is implicit



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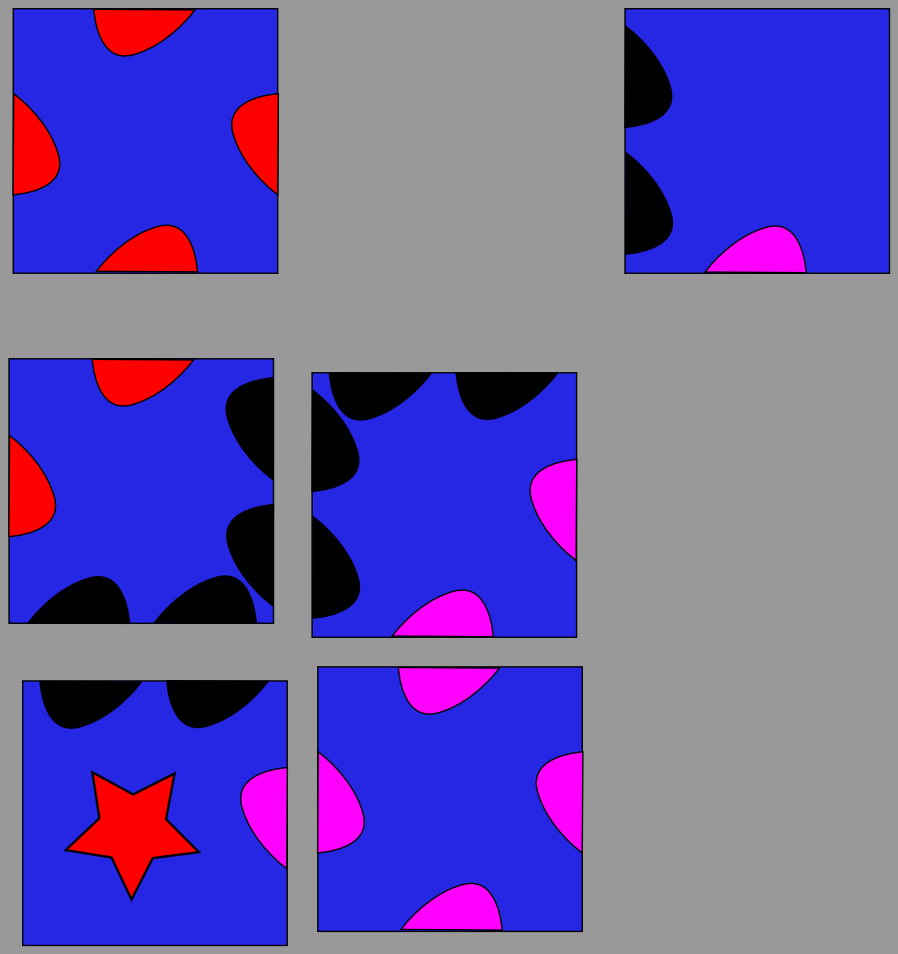

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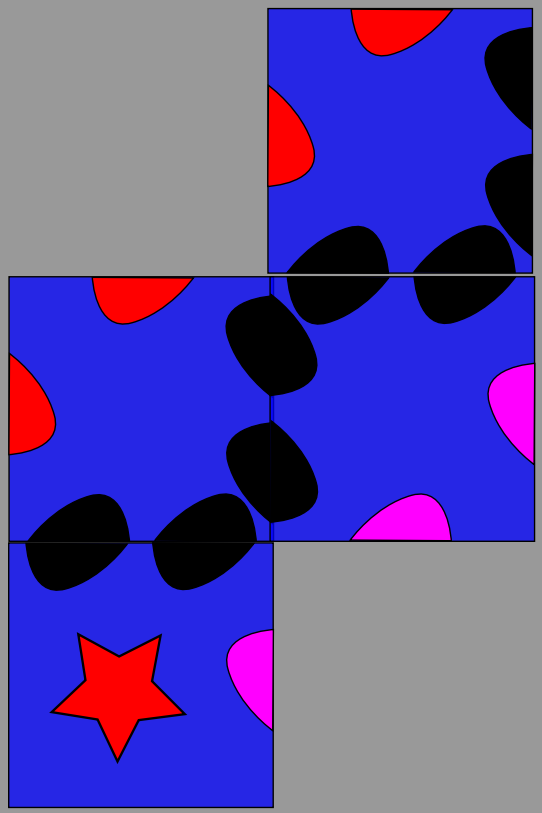

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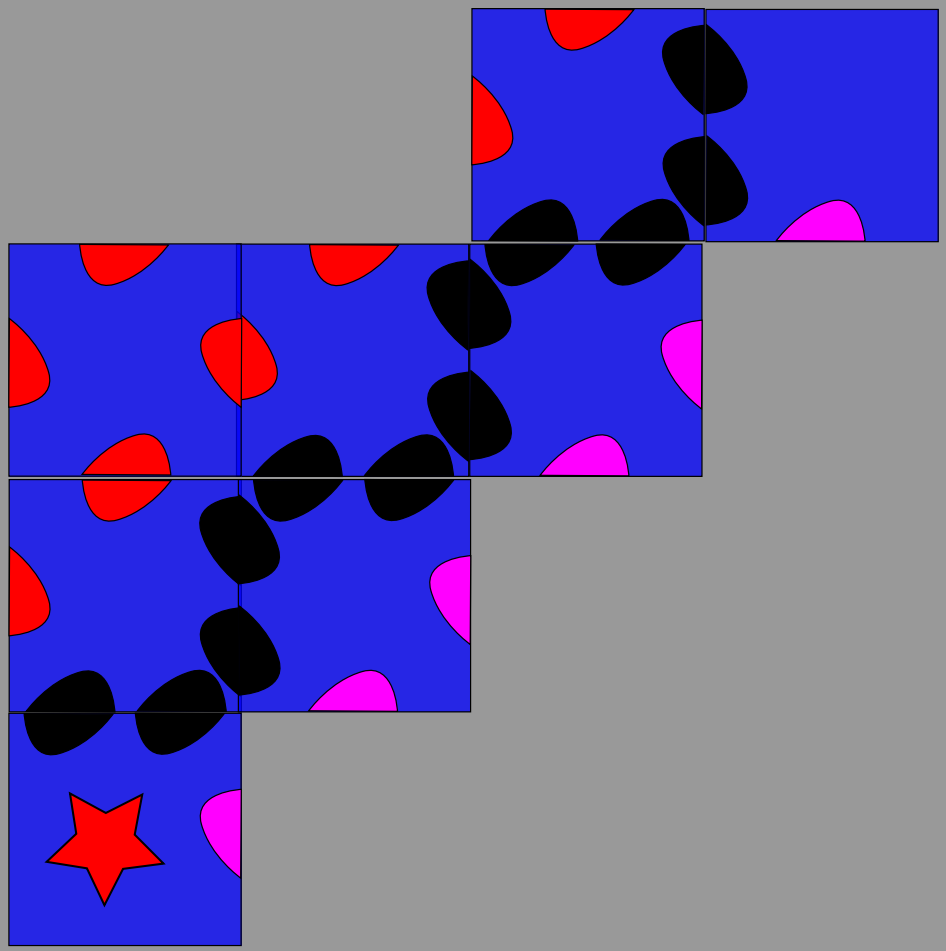

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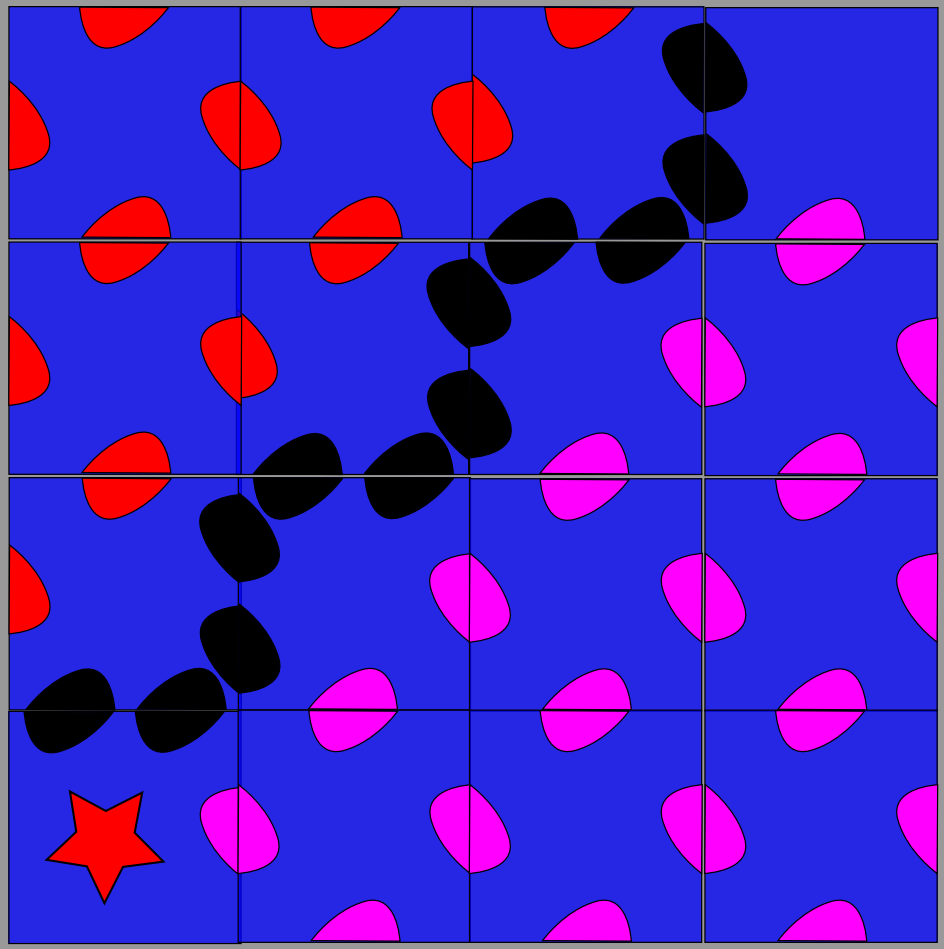

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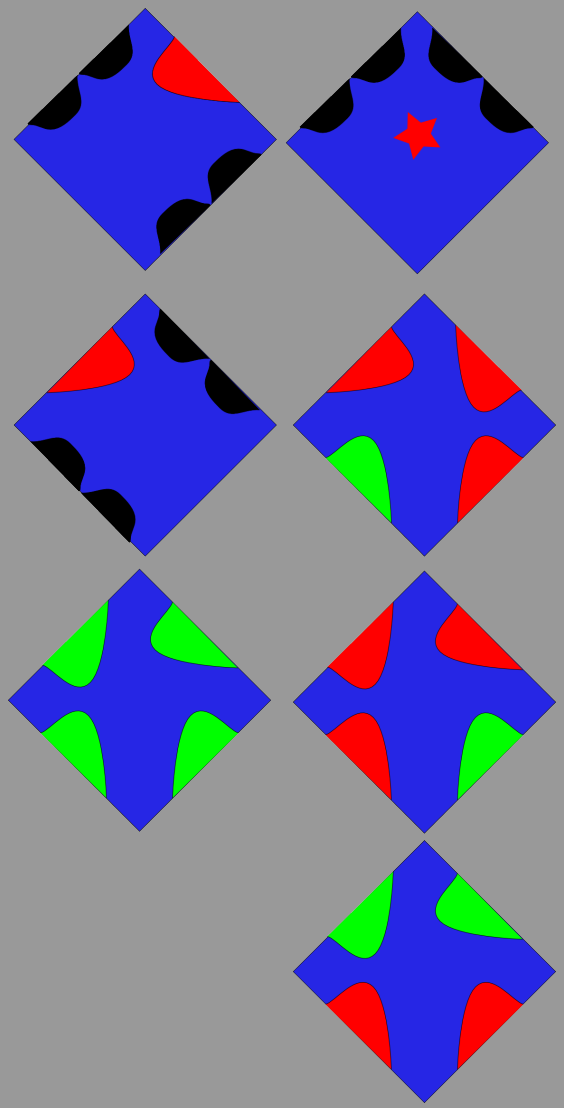

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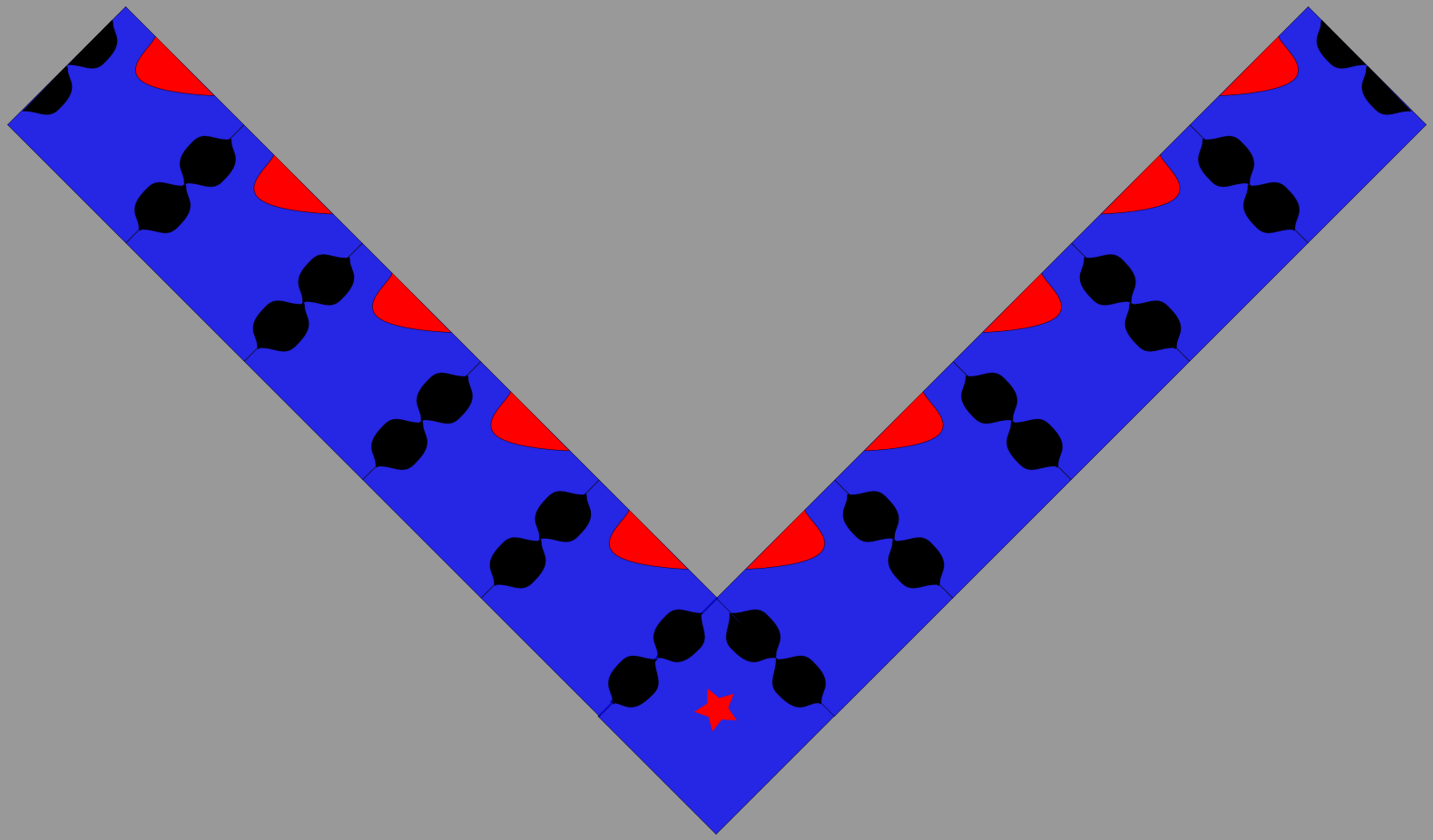

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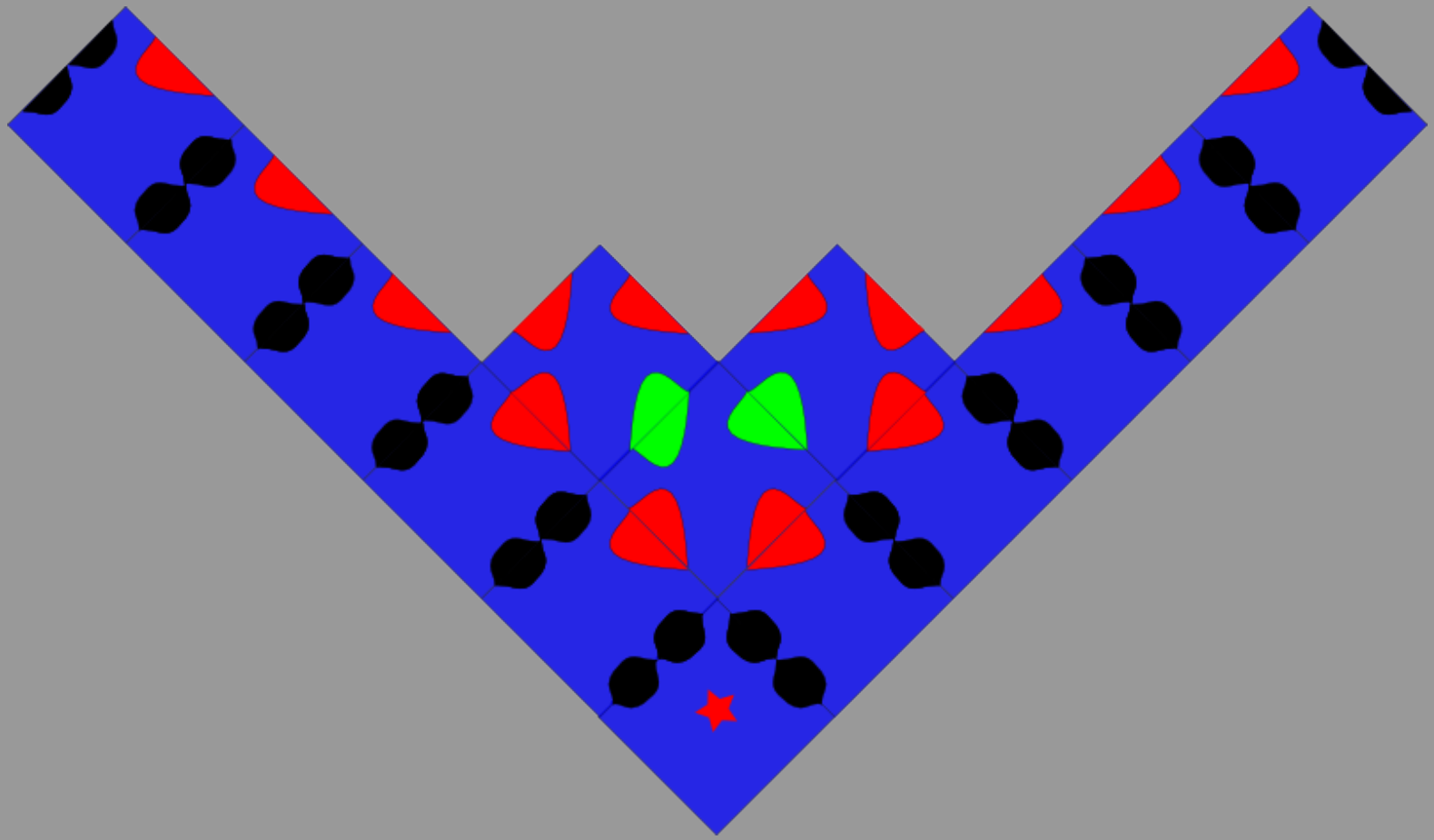

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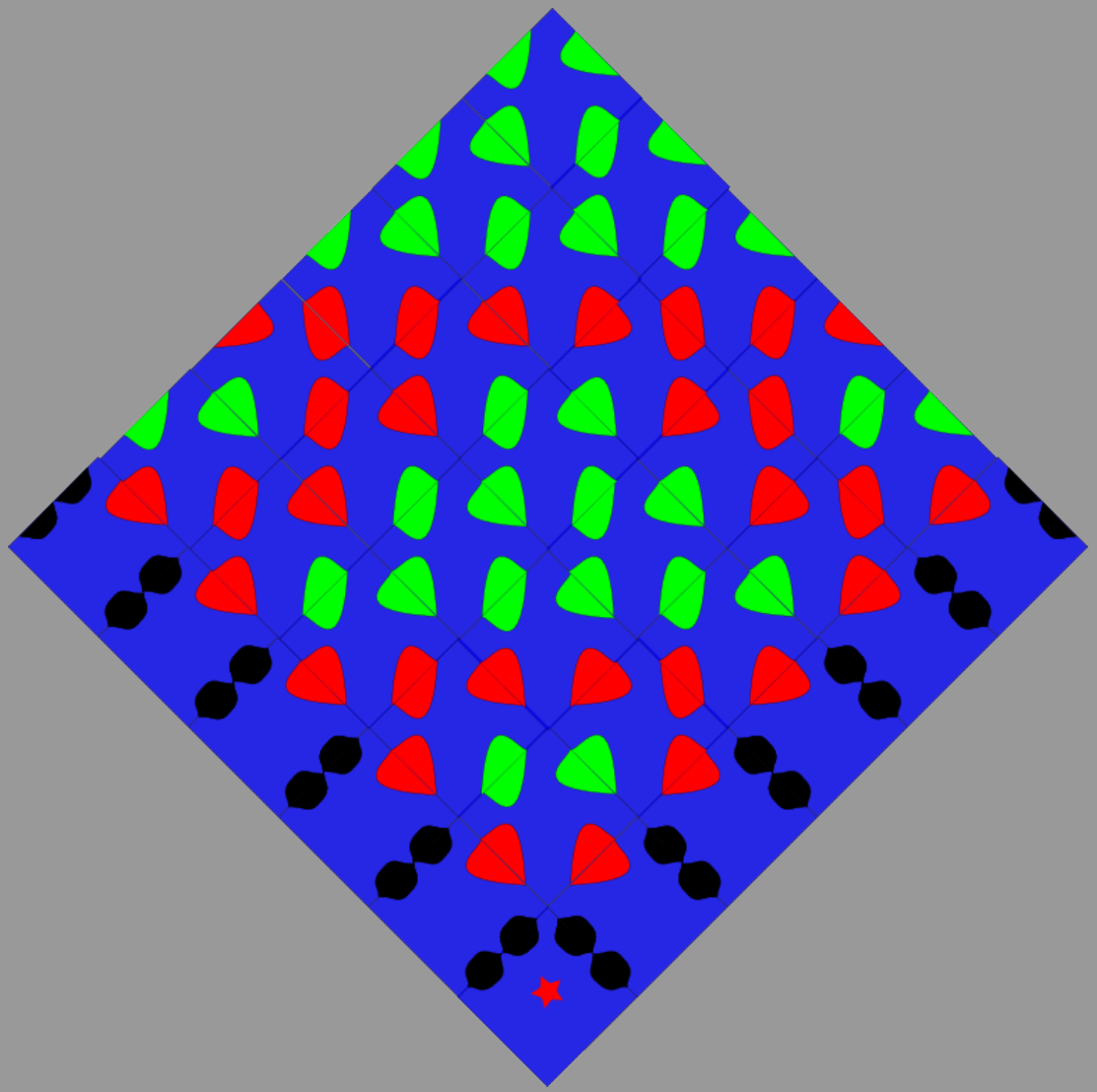

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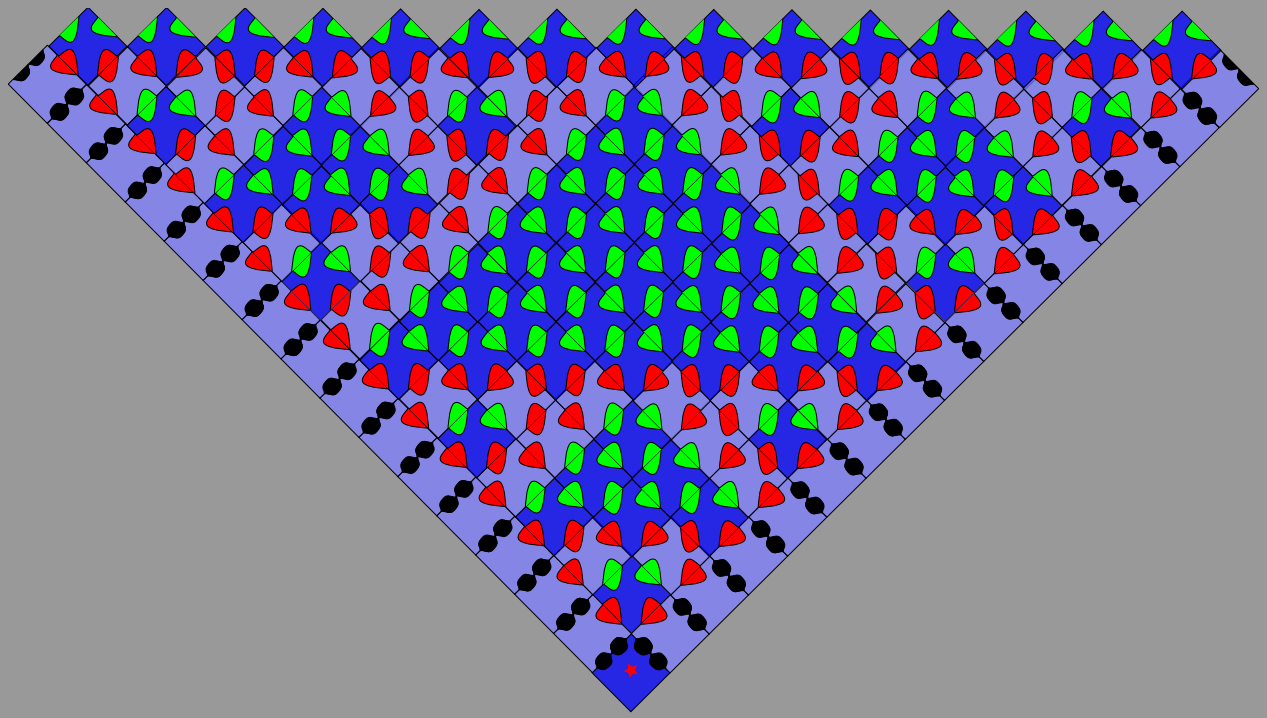
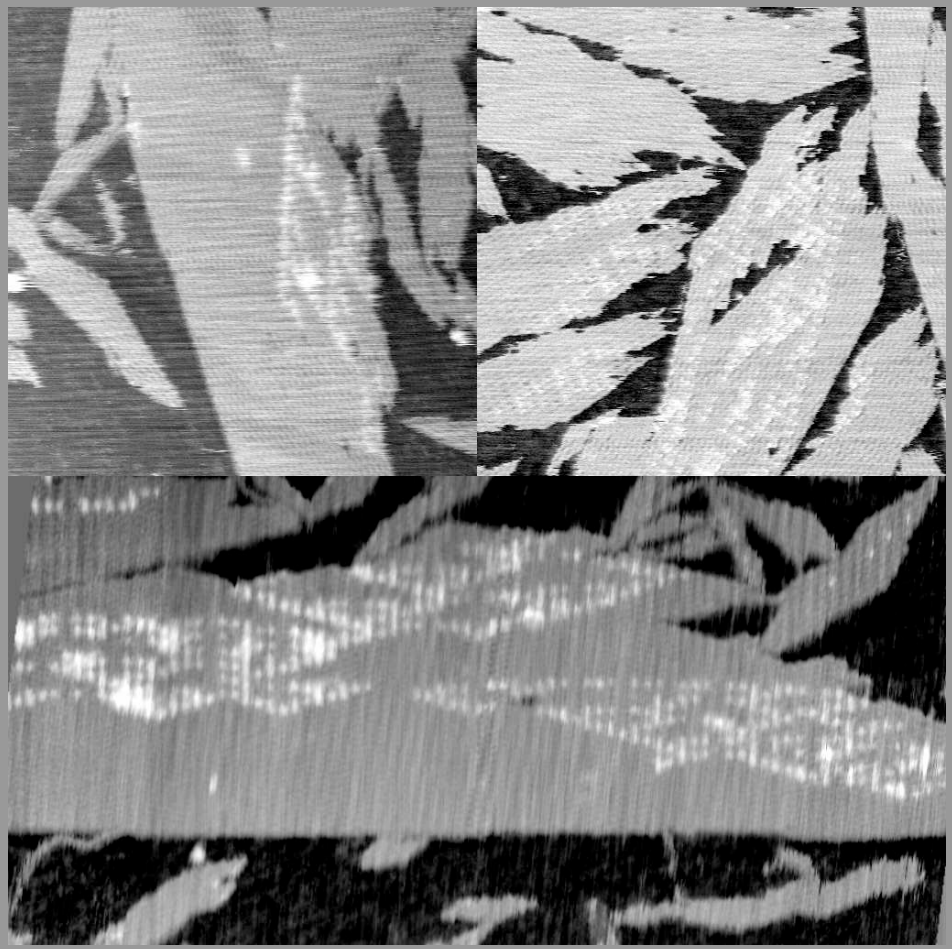


For real:



Credit: Papadakis, Rothemund and Winfree.

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   - Eliminating errors

3. Brevity is. . .
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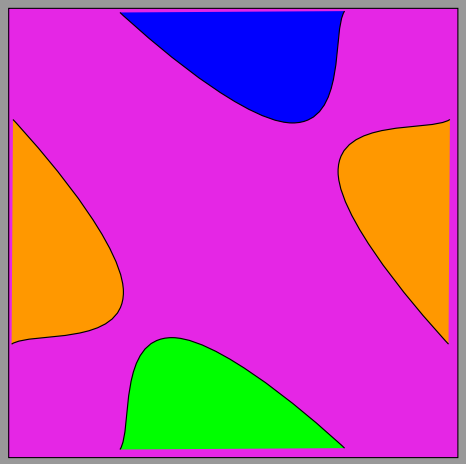
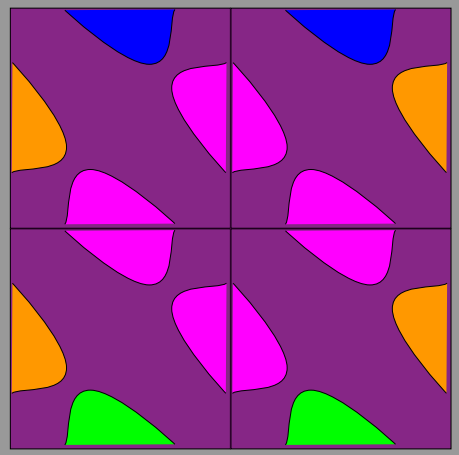
Real life

- Temperature Control is Hard
- Unique Nucleation ("seed") is not realistic
- Unperfect attachments can happen
- Tiles can detach

Proofreading tilesets (Winfree, 2002)





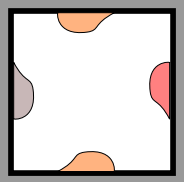
Rate	Attach	Detach
Good link	strong	weak
Bad link	weak	strong

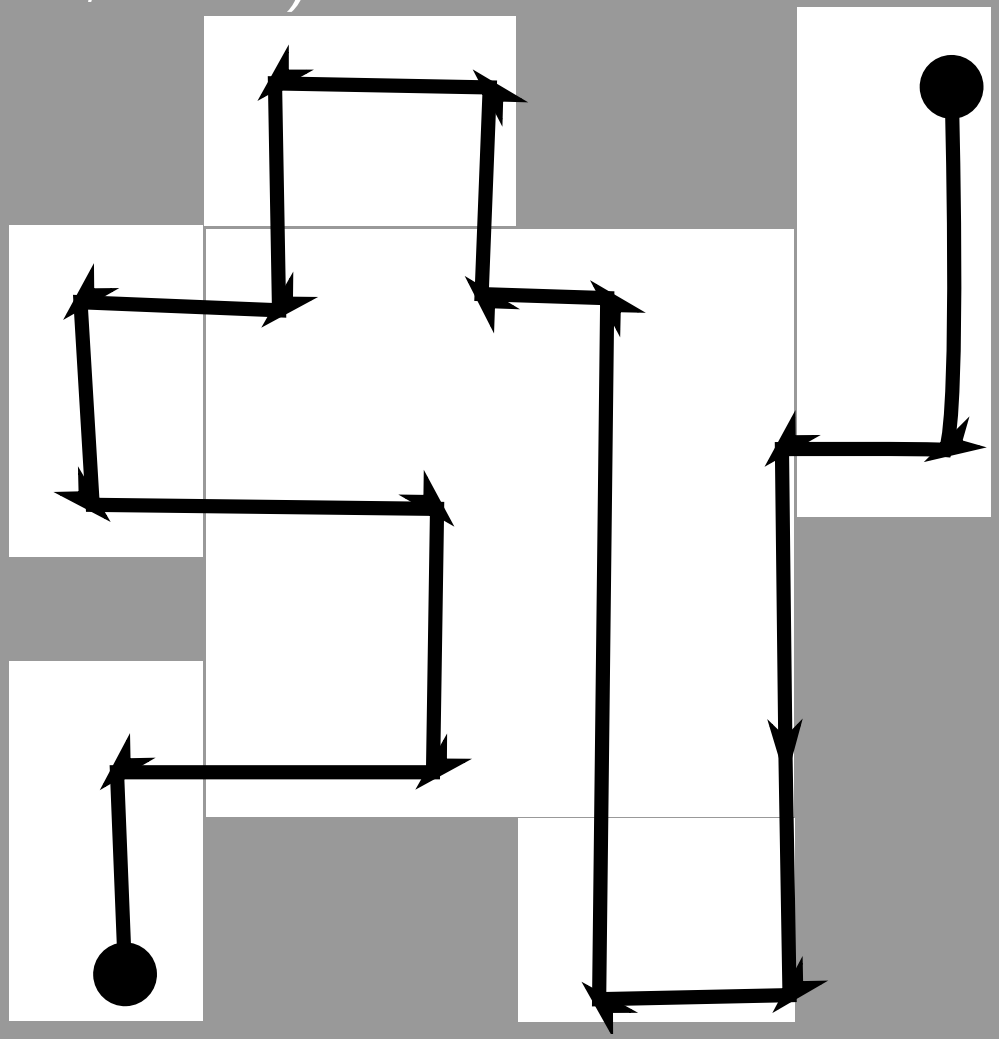
By cutting the tiles, we gain security

Proofreading tilesets, characteristics

- Increase of number of tiles/glues
- Only robust to some types of errors
- Scale is less “nano”.
- Variants: stronger error-resistance, self-healing. . .

Error handling through geometry (Doty, Patitz, Reishus, Shweller, Summers, 2010)





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- Uses *steric protection*
- Resists temperature 1 for an arbitrary long time (fuzzy temperature)
- Resists nucleation errors

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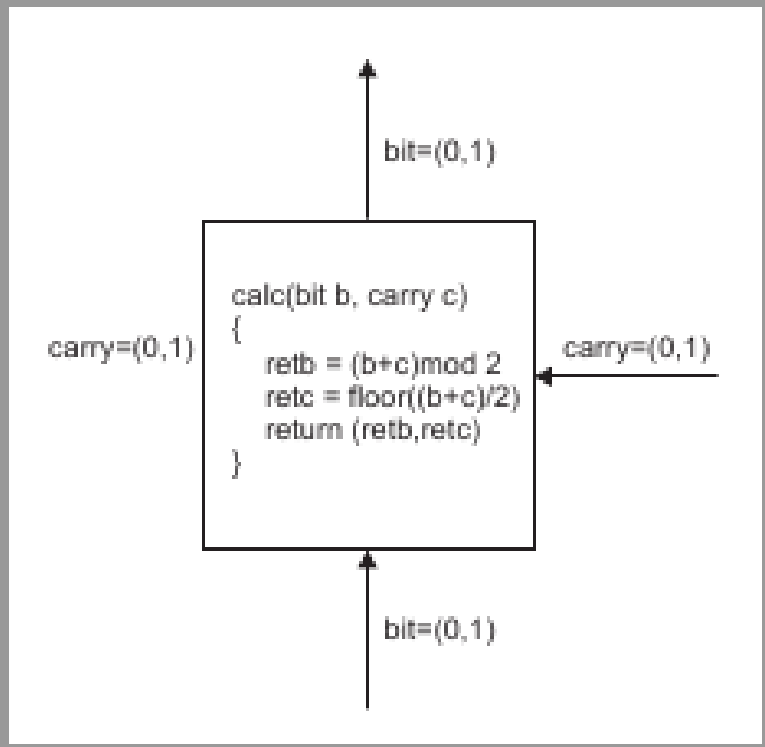
The Stuff Tiles are Made of (Patitz 2009)

- TAM-DSL, `python` Domain Specific Language for tiles
- Tile = tile template + (finite) data
- Tile template: inputs, outputs, computation
- Inputs, outputs = signal
- Joins define the circulation of data.
- Transformations: data on output glues = f(input glues)
- Turns all templates into tiles
- Demonstration (?)



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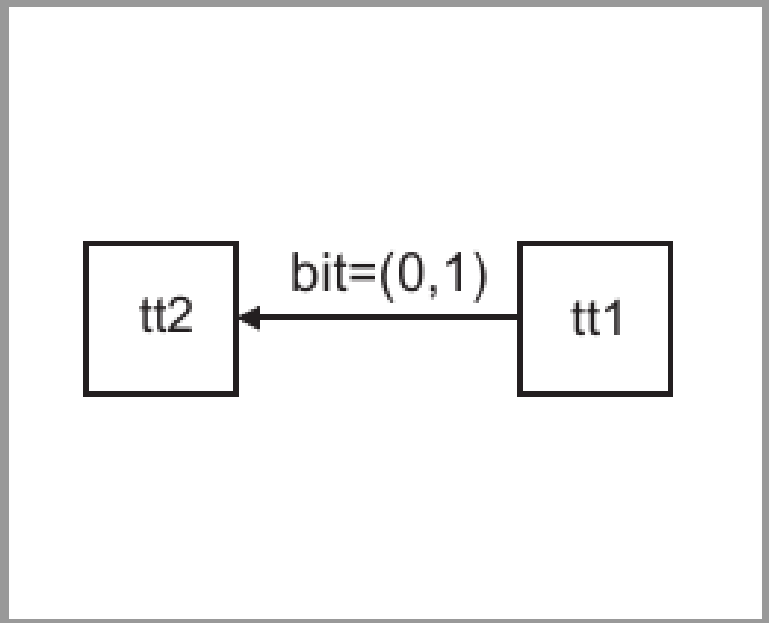

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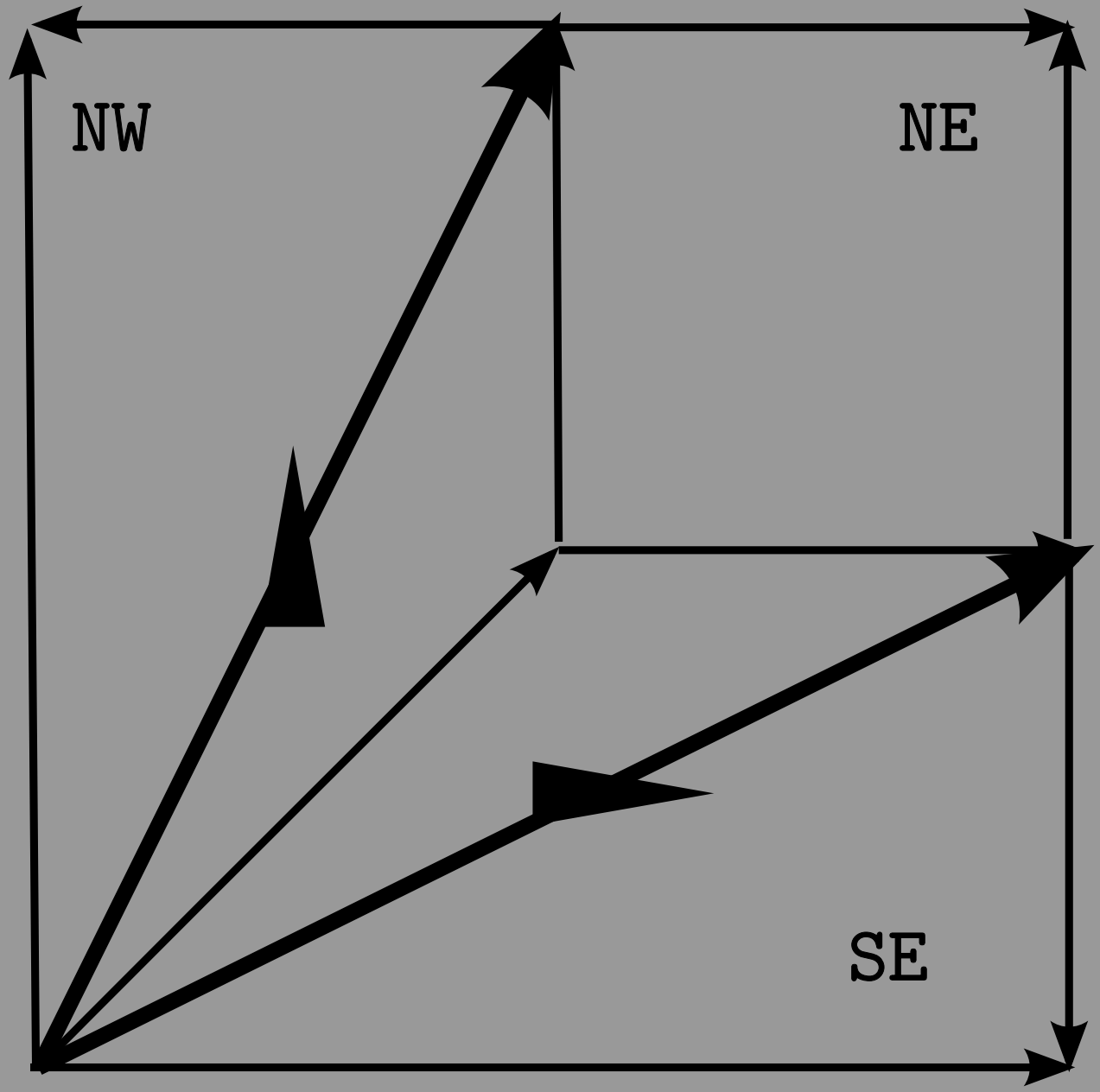

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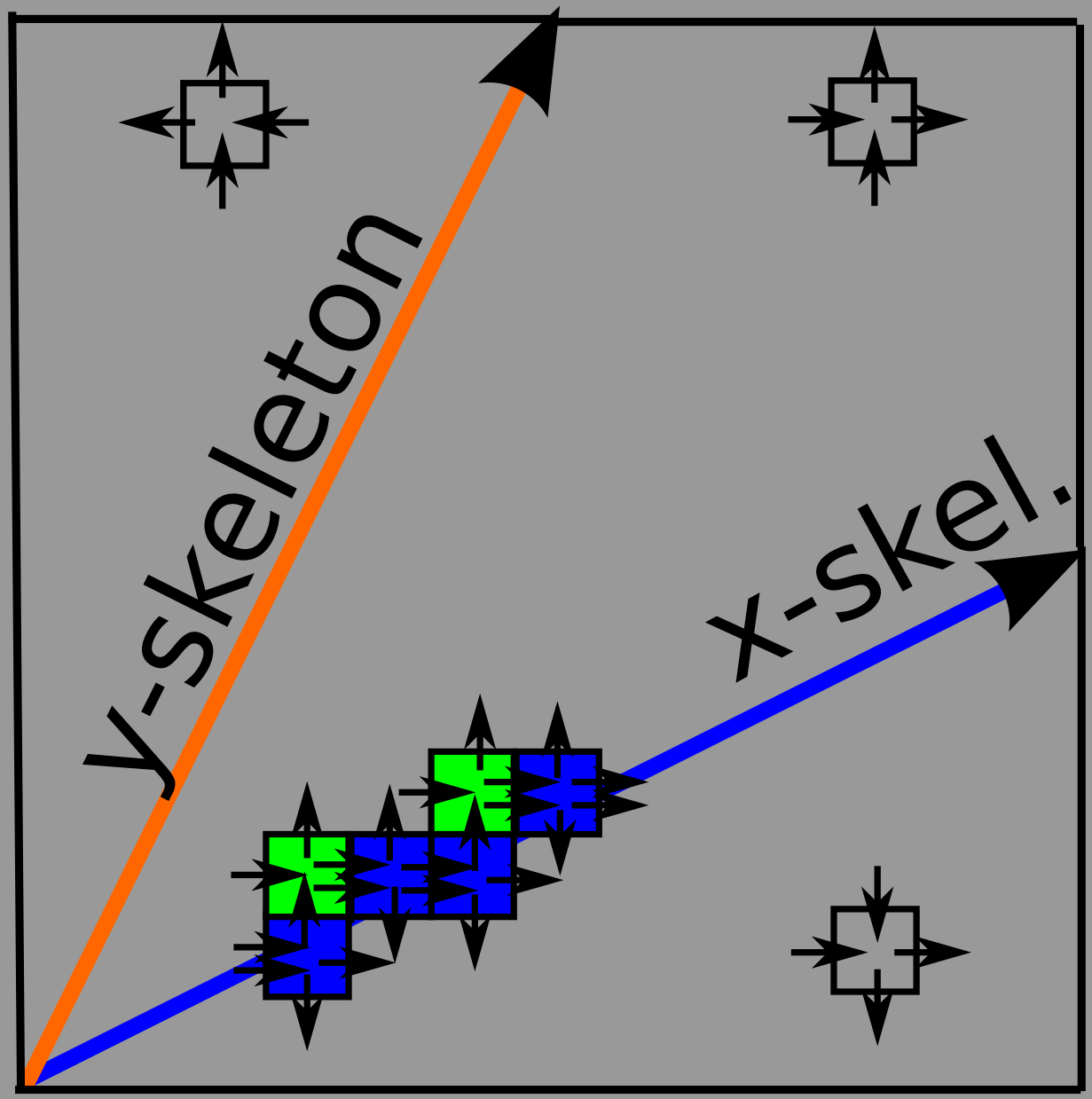

The Stuff Til*ings* are Made of (B 2008)

- Features use geometry
- Cumbersome proofs of tile assembly are removed
- Program directly in a geometric setting
- Start with the pattern and cut into tiles
- Undecidability : Garbage in, Garbage out
- In all generality, exponential number of tiles
- To be implemented. . .

Conclusion

- Geometry rules
- Need for a real programming language
- Thanks
- Questions?