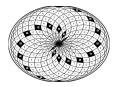
Homology groups of generalized polyomino type tilings

2nd Croatian Combinatorial Days 27 - 28 September Zagreb

Edin Liđan lidjan_edin@hotmail.com





Homology groups of generalized polyomino



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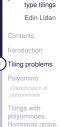
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Tiling, covering, packing

Figure: Tilings in arts and popular culture



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- Region for tiling
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- A finite set Σ of tiles

Definition

- A region M and finite set Σ of tile
- Does Σ tile tiles M?



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- ► Is there a tiling?



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- ► Does Σ tile tiles M?
- ► Is there a tiling?
- How many different tilings are there?



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- Region for tiling
 - Finite region
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 - Surface
- ► A finite set Σ of tiles

Definition

- A region M and finite set Σ of tile
- Does Σ tile tiles M?
- Is there a tiling?
- How many different tilings are there?
- Is a tiling easy to find?

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- Region for tiling
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Definition

- A region *M* and finite set Σ of tile
- Does Σ tile tiles M?
- ► Is there a tiling?
- How many different tilings are there?
- Is a tiling easy to find?
- Is it easy to prove a tiling doesn't exist?



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► Shapes

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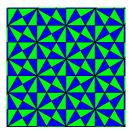


Figure: Triangular lattice (Polyamonds) Homology groups of generalized polyomino type tilings

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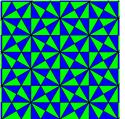




Figure: Triangular lattice (Polyamonds) Figure: Hexagonal lattice (Polyhes)

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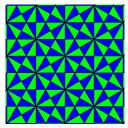


Figure: Triangular lattice (Polyamonds) Figure: Hexagonal lattice (Polyhes)

Figure: Square lattice (Polyominoes)

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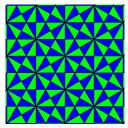


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► periodic



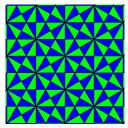


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- ► periodic
- ► aperiodic



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► Polyomino



Figure: Polyomino



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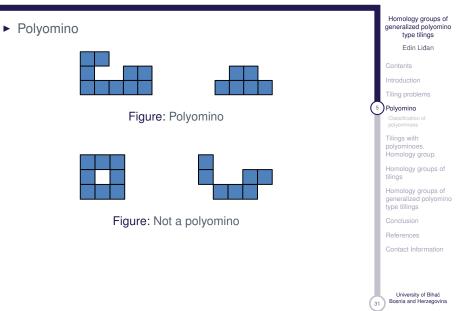
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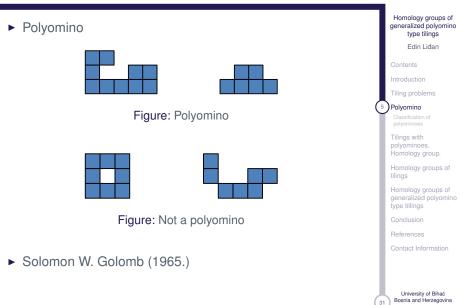
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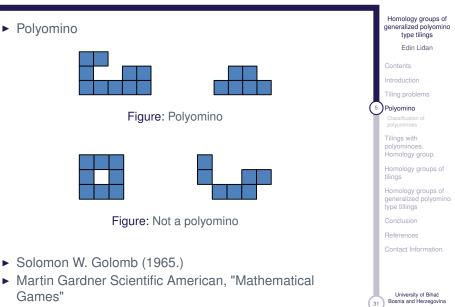














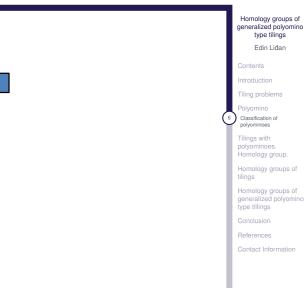


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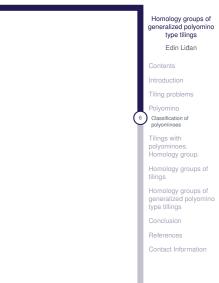


Figure: Trominoes



Figure: Domino





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Figure:

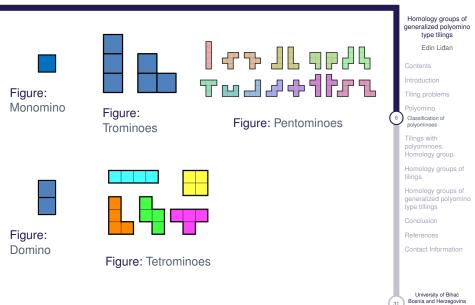
Trominoes

Figure: Monomino

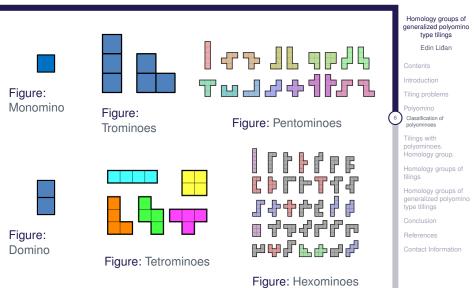
Figure: Domino

Figure: Tetrominoes









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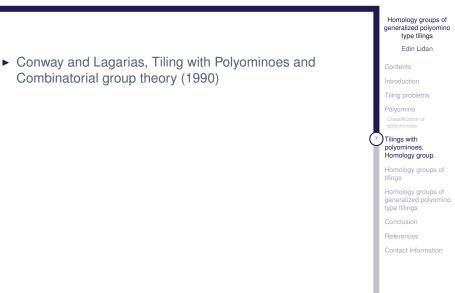


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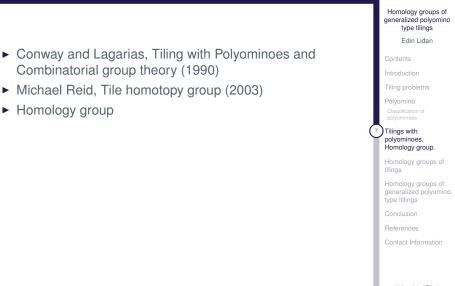




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Homology group

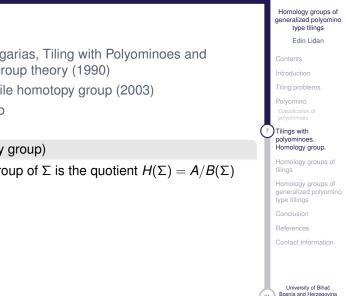




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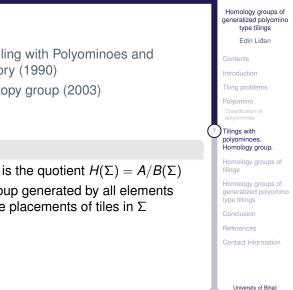
- Conway and Lagarias, Tiling with Polyominoes and Combinatorial group theory (1990)
- Michael Reid, Tile homotopy group (2003)
- Homology group

Definition (Homology group)

The tile homology group of Σ is the quotient $H(\Sigma) = A/B(\Sigma)$



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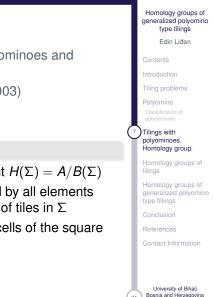
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Definition (Homology group)

The tile homology group of Σ is the quotient $H(\Sigma) = A/B(\Sigma)$

- where B(Σ) is the subgroup generated by all elements corresponding to possible placements of tiles in Σ
- *A* is the free abelian group (on all the cells of the square lattice).



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 We consider whether exists a proper tiling of given region M (surface, surface with the boundary, etc.) subdivided into "cells" like grid with a tiles from a given set Σ.



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- where B(Σ) is the subgroup generated by all elements corresponding to possible placements of tiles in Σ
- A is free Abelian group on all the cells of given region *M*.

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The tile homology group of Σ is the quotient $H(\Sigma) = A/B(\Sigma)$

- where B(Σ) is the subgroup generated by all elements corresponding to possible placements of tiles in Σ
- A is free Abelian group on all the cells of given region *M*.
- A necessary condition for existence of a proper tiling is that the element corresponding to the sum of all cells of M is trivial in the homology group of tilings Σ.





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Example

Is it possible to tile torus chessboard 6×6 with tiles 1 \times 4 (all orientation are allowed)?



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Figure: Torus Chessboard



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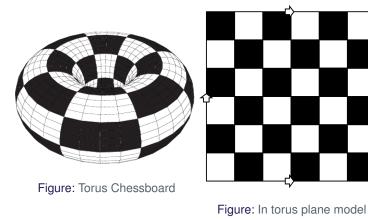
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Example

Is it possible to tile torus chessboard 6×6 with tiles 1 \times 4 (all orientation are allowed)?





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 a_{31} a_{36} a_{33} a_{35} u_{32} u_{34} a_{25} a_{30} u_{26} u_{29} u_{28} a_{19} a_{23} a_{20} $a_{2^{1}}$ $a_{2^{\varDelta}}$ a_{22} a_{13} a_{15} a_{14} u_{17} a_{18} a_{16} \mathcal{A}_8 \mathcal{A}_9 a_{10} \mathcal{A}_7 a_{12} \mathcal{A}_1 a_{6} a_3 \mathcal{A}_{Δ} \mathcal{A}_{5} \mathcal{A}_1 a

Figure: Naming cells

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0 $a_1 + a_2 + a_3 + a_4$ =

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Figure: Naming cells



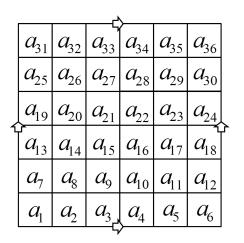


Figure: Naming cells

a_1	+	a_2	+	a 3	+	a_4	=	0
a	+	a ₂	+	a ₄	+	a_5	=	0

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 a_{31} a_{36} a_{33} a_{35} u_{32} u_{34} a_{25} a_{30} u_{26} u_{29} u_{28} a_{19} a_{23} a_{20} $a_{2^{1}}$ $a_{2^{\varDelta}}$ a_{22} a_{13} a_{15} a_{14} u_{17} a_{18} a_{16} \mathcal{A}_8 \mathcal{A}_9 a_{10} \mathcal{A}_7 a_{12} \mathcal{A}_1 a_{6} a_3 \mathcal{A}_{Δ} \mathcal{A}_{5} \mathcal{A}_1 a

$a_1 + a_2 + a_3 + a_4$	=	0
$a_2 + a_3 + a_4 + a_5$	=	0
$a_3 + a_4 + a_5 + a_6$	=	0

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Figure: Naming cells



 a_{31} a_{33} a_{36} a_{32} a_{34} a_{35} a_{25} u_{26} a_{29} a_{30} a_{2} u_{28} a_{19} a_{23} a_{20} a_{21} a_{24} a_{22} a_{16} a_{13} a_{15} a_{18} a_{14} a_{17} \mathcal{A}_8 \mathcal{A}_9 a_{10} \mathcal{A}_7 a_{12} \mathcal{A}_1 a_{6} a_3 \mathcal{A}_{Δ} \mathcal{U}_{5} \mathcal{A}_1 a

$a_1 + a_2 + a_3 + a_4$	=	0
$a_2 + a_3 + a_4 + a_5$	=	0
$a_3 + a_4 + a_5 + a_6$	=	0
$a_4 + a_5 + a_6 + a_1$	=	0

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Figure: Naming cells



 a_{31} a_{36} a_{33} a_{35} a_{32} u_{34} a_{25} u_{26} a_{30} u_{29} u_{28} a_{19} a_{23} a_{20} $a_{2^{1}}$ $a_{2^{4}}$ a_{22} a_{13} a_{15} a_{14} u_{17} a_{18} a_{16} \mathcal{A}_8 \mathcal{A}_9 a_{10} \mathcal{A}_7 a_{12} \mathcal{A}_1 a_{6} a_3 \mathcal{A}_{Δ} \mathcal{A}_{5} \mathcal{A}_1 a

$a_1 + a_2 + a_3 + a_4$	=	С
$a_2 + a_3 + a_4 + a_5$	=	0
$a_3 + a_4 + a_5 + a_6$	=	С
$a_4 + a_5 + a_6 + a_1$	=	С
$a_5 + a_6 + a_1 + a_2$	=	0

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Figure: Naming cells



Homology groups of generalized polyomino

 a_{31} a_{36} a_{33} a_{35} u_{32} u_{34} a_{25} a_{30} u_{26} u_{28} *a*₁₉ a_{23} a_{20} a_{21} $a_{2^{2}}$ a_{22} a_{13} a_{15} a_{14} a_{16} u_{17} a_{18} \mathcal{A}_8 \mathcal{A}_9 a_{10} \mathcal{A}_7 a_{12} \mathcal{A}_1 a_{6} a_3 $\mathcal{A}_{\mathcal{A}}$ \mathcal{U}_{5} \mathcal{A}_1

$a_1 + a_2 + a_3 + a_4$	=	0
$a_2 + a_3 + a_4 + a_5$	=	0
$a_3 + a_4 + a_5 + a_6$	=	0
$a_4 + a_5 + a_6 + a_1$	=	0
$a_5 + a_6 + a_1 + a_2$	=	0

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Figure: Naming cells



 a_{31} a_{36} a_{33} a_{35} u_{32} u_{34} a_{25} a_{30} u_{26} u_{28} *a*₁₉ a_{23} a_{20} $a_{2^{1}}$ $a_{2^{\varDelta}}$ a_{22} a_{13} a_{15} a_{14} u_{17} a_{18} a_{16} \mathcal{A}_8 \mathcal{A}_9 a_{10} \mathcal{A}_7 a_{12} \mathcal{A}_1 a_{6} a_{3} \mathcal{A}_{Δ} \mathcal{A}_{5} \mathcal{A}_1

Figure: Naming cells

$a_1 + a_2 + a_3 + a_4$	=	0
$a_2 + a_3 + a_4 + a_5$	=	0
$a_3 + a_4 + a_5 + a_6$	=	0
$a_4 + a_5 + a_6 + a_1$	=	0
$a_5 + a_6 + a_1 + a_2$	=	0

 relation in finite group

$$a_1 = a_5 = a_3$$

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 a_{31} a_{36} a_{33} a_{35} u_{32} u_{34} a_{25} u_{26} a_{30} u_{28} a_{19} a_{20} a_{21} a_{23} $a_{2^{\varDelta}}$ a_{22} a_{13} a_{15} a_{14} u_{17} a_{18} a_{16} \mathcal{A}_9 a_{10} a_8 \mathcal{A}_7 a_{12} \mathcal{A}_1 a_{6} a_{3} \mathcal{A}_{Δ} \mathcal{U}_{5} \mathcal{A}_1

Figure: Naming cells

$a_1 + a_2 + a_3 + a_4$	=	0
$a_2 + a_3 + a_4 + a_5$	=	0
$a_3 + a_4 + a_5 + a_6$	=	0
$a_4 + a_5 + a_6 + a_1$	=	0
$a_5 + a_6 + a_1 + a_2$	=	0

 relation in finite group

$$a_1 = a_5 = a_3$$

$$a_2 = a_6 = a_4$$

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			بر	<u> </u>		
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	a_7	$a_{\!8}$
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	a_8	a_7	a_8	a_7	a_{8}
ì	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	$a_{\!_8}$	a_7	a_8
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
			,	/		

Figure: Equivalent cells

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		r	<u> </u>	\succ		
	a_7	$a_{\!\!8}$	a_7	a_{8}	a_7	a_8
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	a_8	a_7		a_7	a_{8}
١	a_{l}	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!_8}$	a_7	$a_{\!_8}$	a_7	a_8
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
			,			

Figure: Equivalent cells

► if we put now tile 1 × 4 on our chessboard

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			بر	<u> </u>			
	a_7	$a_{\!8}$	a_7	a_{8}	a_7	a_8	
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	
	a_7	a_8	a_7	a_8	a_7	a_{8}	
ĩ	a_{l}	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	r
	a_7	$a_{\!_8}$	a_7	$a_{\!_8}$	a_7	a_8	
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2	
			,				

 if we put now tile 1 × 4 on our chessboard

$$2a_1 + 2a_2 = 0$$

Figure: Equivalent cells

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	_		بر	<u> </u>			
í	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	a_7	a_8	
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	
	a_7	a_8	a_7	a_8	a_7	a_{8}	
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	ſ
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	$a_{\!_8}$	a_7	a_8	
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2	
			<u> </u> ,				

 if we put now tile 1 × 4 on our chessboard

$$2a_1 + 2a_2 = 0$$

$$2a_7 + 2a_8 = 0$$

Figure: Equivalent cells

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			^				
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	a_7	a_{8}	
	a_{l}	a_2	a_{1}	a_2	a_{l}	a_2	
	a_7	a_8	a_7	a_8	a_7	a_{8}	
٦	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	ſ
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	$a_{\!_8}$	a_7	a_8	
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2	
			—,				

► if we put now tile 1 × 4 on our chessboard

$$2a_1 + 2a_2 = 0 2a_1 + 2a_7 = 0$$

$$2a_7 + 2a_8 = 0$$

Figure: Equivalent cells

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			ť	<u> </u>			
	a_7	$a_{\!_8}$	a_7	$a_{\!_8}$	a_7	$a_{\!8}$	
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	
	a_7	$a_{\!8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	
٦	$\int a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	ſ
	a_7	a_8	a_7	$a_{\!_8}$	a_7	a_8	
	$a_{\rm l}$	a_2	a_{1}	a_2	$a_{\rm l}$	a_2	

► if we put now tile 1 × 4 on our chessboard

$$2a_1 + 2a_2 = 0$$

$$2a_7 + 2a_8 = 0$$

$$2a_1 + 2a_7 = 0$$

 $2a_2 + 2a_8 = 0$

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		/			
a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
a_{l}	a_2	a_{l}	a_2	a_{l}	a_2
a_7	$a_{\!8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
a_{1}	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	a_8	a_7	a_8	a_7	a_8
$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
	$\begin{bmatrix} a_1 \\ a_7 \\ a_1 \\ a_7 \\ a_7 \end{bmatrix}$	$\begin{array}{c c} a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

► if we put now tile 1 × 4 on our chessboard

$$2a_1 + 2a_2 = 0$$

 $2a_7 + 2a_8 = 0$

$$2a_1 + 2a_7 = 0$$

 $2a_2 + 2a_8 = 0$

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Figure: Equivalent cells

► 4 generators a₁, a₂, a₇, a₈



		^			
a_7	$a_{\!_8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	$a_{\!8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	a_8	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
	a_1 a_7 a_1 a_7	$\begin{array}{c c} a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline a_1 & a_2 \\ \hline a_7 & a_8 \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

- if we put now tile 1 × 4 on our chessboard
 - $\begin{array}{ll} 2a_1+2a_2=0 & 2a_1+2a_7=0 \\ 2a_7+2a_8=0 & 2a_2+2a_8=0 \end{array}$

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

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		^			
a_7	$a_{\!_8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	$a_{\!8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	a_8	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
	a_1 a_7 a_1 a_7	$\begin{array}{c c} a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline a_1 & a_2 \\ \hline a_7 & a_8 \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

- ► if we put now tile 1 × 4 on our chessboard
 - $2a_1 + 2a_2 = 0$ $2a_1 + 2a_2 = 0$ $2a_2 + 2a_3 = 0$ $2a_3 + 2a_3 = 0$

 $2a_1 + 2a_7 = 0$ $2a_2 + 2a_8 = 0$

Figure: Equivalent cells

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

▶ 9 cells *a*₁,

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		^			
a_7	$a_{\!_8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	$a_{\!8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	a_8	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
	$\begin{array}{c} a_1 \\ a_7 \\ a_1 \\ a_7 \\ a_7 \end{array}$	$\begin{array}{c c} a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline a_1 & a_2 \\ \hline a_7 & a_8 \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

- ► if we put now tile 1 × 4 on our chessboard
 - $2a_1 + 2a_2 = 0$ $2a_2$ $2a_7 + 2a_8 = 0$ $2a_2$

```
2a_1 + 2a_7 = 0
2a_2 + 2a_8 = 0
```

Figure: Equivalent cells

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

▶ 9 cells *a*₁, 9 cells *a*₂,

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		^			
a_7	$a_{\!_8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	$a_{\!8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	a_8	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
	$\begin{array}{c} a_1 \\ a_7 \\ a_1 \\ a_7 \\ a_7 \end{array}$	$\begin{array}{c c} a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline a_1 & a_2 \\ \hline a_7 & a_8 \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

- ► if we put now tile 1 × 4 on our chessboard
 - $2a_1 + 2a_2 = 0$ $2a_1$ $2a_7 + 2a_8 = 0$ $2a_2$

 $2a_1 + 2a_7 = 0$ $2a_2 + 2a_8 = 0$

Figure: Equivalent cells

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

▶ 9 cells *a*₁, 9 cells *a*₂, 9 cells *a*₇,

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		^			
a_7	$a_{\!_8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	$a_{\!8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
a_7	a_8	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2
	a_1 a_7 a_1 a_7	$\begin{array}{c c} a_1 & a_2 \\ \hline a_7 & a_8 \\ \hline a_1 & a_2 \\ \hline a_7 & a_8 \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

- if we put now tile 1 × 4 on our chessboard
 - $\begin{array}{ll} 2a_1+2a_2=0 & 2a_1+2a_7=0 \\ 2a_7+2a_8=0 & 2a_2+2a_8=0 \end{array}$

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

▶ 9 cells a_1 , 9 cells a_2 , 9 cells a_7 , 9 cells a_8

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			^			
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!_8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
ì	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!_8}$	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2

- if we put now tile 1 × 4 on our chessboard
 - $\begin{array}{ll} 2a_1+2a_2=0 & 2a_1+2a_7=0 \\ 2a_7+2a_8=0 & 2a_2+2a_8=0 \end{array}$

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

▶ 9 cells a_1 , 9 cells a_2 , 9 cells a_7 , 9 cells a_8

 $a_1 + a_2 + a_7 + a_8$

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			^			
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!_8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
ì	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!_8}$	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2

- if we put now tile 1 × 4 on our chessboard
 - $\begin{array}{ll} 2a_1+2a_2=0 & 2a_1+2a_7=0 \\ 2a_7+2a_8=0 & 2a_2+2a_8=0 \end{array}$

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

▶ 9 cells a_1 , 9 cells a_2 , 9 cells a_7 , 9 cells a_8

 $a_1 + a_2 + a_7 + a_8$

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			^			
	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}	a_7	$a_{\!\!8}$
	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!_8}$	a_7	$a_{\!\scriptscriptstyle 8}$	a_7	a_{8}
ì	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	$a_{\rm l}$	a_2
	a_7	$a_{\!_8}$	a_7	$a_{\!_8}$	a_7	$a_{\!\!8}$
	$a_{\rm l}$	a_2	a_{l}	a_2	$a_{\rm l}$	a_2

- if we put now tile 1 × 4 on our chessboard
 - $\begin{array}{ll} 2a_1+2a_2=0 & 2a_1+2a_7=0 \\ 2a_7+2a_8=0 & 2a_2+2a_8=0 \end{array}$

- ▶ 4 generators *a*₁, *a*₂, *a*₇, *a*₈
- Homology groups

 $< G(a_1, a_2, a_7, a_8 | 2a_1 + 2a_2, 2a_7 + 2a_8, 2a_1 + 2a_7, 2a_2 + 2a_8) >$

▶ 9 cells a_1 , 9 cells a_2 , 9 cells a_7 , 9 cells a_8

 $a_1 + a_2 + a_7 + a_8$

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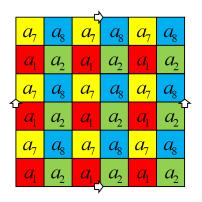
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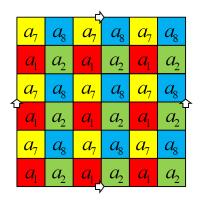
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9 red cells

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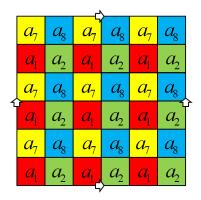
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- 9 red cells
- 9 green cells

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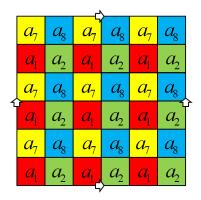
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- 9 red cells
- 9 green cells
- ► 9 yellow cells

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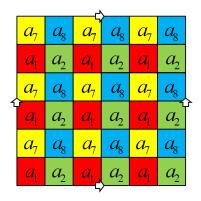


Figure: Coloring the Chessboard

- 9 red cells
- 9 green cells
- 9 yellow cells
- 9 blue cells



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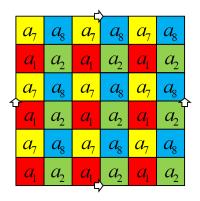
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- 9 red cells
- 9 green cells
- 9 yellow cells
- 9 blue cells
- every tile 1 × 4 covering

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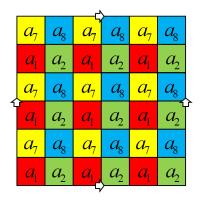
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- 9 red cells
- 9 green cells
- 9 yellow cells
- 9 blue cells
- every tile 1 × 4 covering
 - 2 red and 2 green

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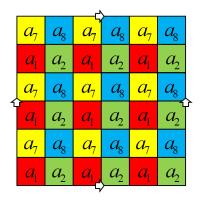
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- 9 red cells
- 9 green cells
- 9 yellow cells
- 9 blue cells
- every tile 1 × 4 covering
 - 2 red and 2 green
 - 2 yellow and 2 blue

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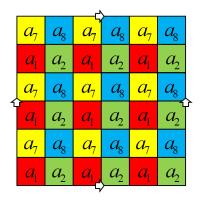
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- 9 red cells
- 9 green cells
- 9 yellow cells
- 9 blue cells
- every tile 1 × 4 covering
 - 2 red and 2 green
 - 2 yellow and 2 blue
 - 2 red and 2 yellow

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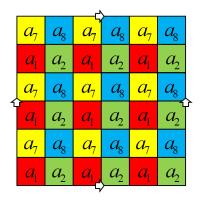
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- 9 red cells
- 9 green cells
- 9 yellow cells
- 9 blue cells
- every tile 1 × 4 covering
 - 2 red and 2 green
 - 2 yellow and 2 blue
 - 2 red and 2 yellow
 - 2 green and 2 blue

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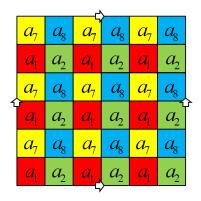
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- 9 red cells
- 9 green cells
- 9 yellow cells
- 9 blue cells
- every tile 1 × 4 covering
 - 2 red and 2 green
 - 2 yellow and 2 blue
 - 2 red and 2 yellow
 - 2 green and 2 blue
- tiling is not possible

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	_			لے	<u> </u>				
a_{11}	a_{12}								
a_{l}	a_2	a_{l}	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2
a_{11}	<i>a</i> ₁₂	a_{11}	<i>a</i> ₁₂	a_{11}	<i>a</i> ₁₂	a_{11}	a_{12}	a_{11}	<i>a</i> ₁₂
a_1	a_2	a_{1}	a_2	$a_{\rm l}$	a_2	a_1	a_2	$a_{\rm l}$	a_2
<i>a</i> ₁₁	<i>a</i> ₁₂								
a_1	a_2	$a_{\rm l}$	a_2	a_{1}	a_2	a_{1}	a_2	$a_{\rm l}$	a_2
a_{11}	<i>a</i> ₁₂	<i>a</i> ₁₁	<i>a</i> ₁₂						
$a_{\rm l}$	a_2	$a_{\rm l}$	a_2	a_1	a_2	$a_{\rm l}$	a_2	a_{1}	a_2
<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₁	a_{12}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₁	<i>a</i> ₁₂
a_1	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_{1}	a_2

Theorem

The torus chessboard of dimension $(4k + 2) \times (4k + 2)$ can be not tiling with the tile 1 × 4.



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Example

Is it possible to tile torus chessboard 10 \times 10 with T - tetrominoes? (all orientation are allowed)



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Example

Is it possible to tile torus chessboard 10 \times 10 with T - tetrominoes? (all orientation are allowed)

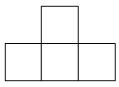


Figure: T - tetramino

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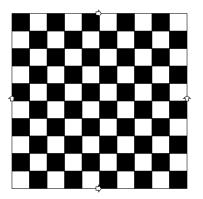


Figure: In torus plane model

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 a_{61} a_{51} a_{41} a_{31} a_{21} a_{11} a,

Figure: In torus plane model

Figure: Naming cells

 a_{95}

 a_{85}

 a_{75} a_{76} a_{77} a_{78} a_{79} a_{80}

 a_{25} a_{26} a_{27} a_{28} a_{29} a_{30}

 a_{15}

 a_5

 a_{96}

 a_{86} a_{87} a_{88} a_{so} a_{00}

 a_{66}

 a_{56}

 a_{36} a_{37}

 a_{16} a_{17} a_{18} a_{19} a_{20}

 a_6 a_7 a_8 a_0 a_{10}

 a_{97} a_{98}

 a_{67} a_{68}

 a_{57} a_{58} a_{99} a_{100}

 a_{69} a_{70}

 a_{59} a_{60}

 a_{49} a_{50}

 a_{39} a_{40}

 a_{38}

 $a_{\!_{94}}$

 a_{74}

 a_{34} a_{35}

a a24

 a_{92}

 $a_{\!82}$ a_{83} a_{84}

 a_{62}

 a_{52} a_{52} a_{54} a_{55}

 a_{42}

 a_{32} a_{33}

 a_{22} a_{23}

 a_{12} a_{13} a_{14}

 a_2

 a_{03}

 a_{63} a_{64} a_{65}

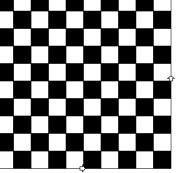
 a_{43} 1 a₄₄ a_{45} a_{46} a_{47} a_{48}

 a_3 a_4

 a_{91}

 $a_{\!81}$

 a_{71} a_{77} a_{73}





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				<u>г</u>	\rightarrow				
a_{91}	a_{92}	a_{93}	a_{94}	a_{95}	a_{96}	a ₉₇	a_{98}	a ₉₉	a_{100}
a_{81}	$a_{\!82}$	a_{83}	$a_{\!_{84}}$	a_{85}	a_{86}	$a_{\!_{87}}$	$a_{\!_{88}}$	$a_{\!89}$	$a_{\!90}$
a_{71}	a_{72}	a_{73}	a_{74}	a_{75}	a_{76}	a ₇₇	a_{78}	a_{79}	$a_{\!_{80}}$
a_{61}	a_{62}	<i>a</i> ₆₃	<i>a</i> ₆₄	a ₆₅	a ₆₆	a ₆₇	<i>a</i> ₆₈	a ₆₉	a_{70}
a_{51}	<i>a</i> ₅₂	a ₅₃	a ₅₄	a ₅₅	a ₅₆	a ₅₇	a ₅₈	a ₅₉	a_{60}
a_{41}	<i>a</i> ₄₂	<i>a</i> ₄₃	<i>a</i> ₄₄	a ₄₅	a_{46}	a ₄₇	<i>a</i> ₄₈	<i>a</i> ₄₉	a_{50}
a_{31}	<i>a</i> ₃₂	a ₃₃	a ₃₄	a ₃₅	a ₃₆	a ₃₇	a ₃₈	<i>a</i> ₃₉	a_{40}
a_{21}	<i>a</i> ₂₂	<i>a</i> ₂₃	<i>a</i> ₂₄	a ₂₅	a_{26}	a ₂₇	a_{28}	a_{29}	a_{30}
<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	a_{19}	a_{20}
$a_{\rm I}$	a_2	a_3	a_4	a_{5}	a_6	a_7	a_8	a_9	a_{10}

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				ť	<u> </u>				
a_{91}	a_{92}	a_{93}	$a_{\!94}$	a_{95}	a_{96}	a ₉₇	$a_{\!98}$	a ₉₉	a_{100}
a_{81}	$a_{\!82}$	a ₈₃	<i>a</i> ₈₄	a_{85}	a ₈₆	a ₈₇	$a_{\!_{88}}$	a ₈₉	$a_{\!_{90}}$
a_{71}	<i>a</i> ₇₂	<i>a</i> ₇₃	<i>a</i> ₇₄	a ₇₅	a_{76}	<i>a</i> ₇₇	a_{78}	<i>a</i> ₇₉	$a_{\!_{80}}$
a_{61}	a_{62}	<i>a</i> ₆₃	<i>a</i> ₆₄	a_{65}	a ₆₆	a ₆₇	a ₆₈	a ₆₉	a_{70}
<i>a</i> ₅₁	<i>a</i> ₅₂	<i>a</i> ₅₃	a ₅₄	a ₅₅	a ₅₆	a ₅₇	a ₅₈	a ₅₉	a_{60}
a ₄₁	<i>a</i> ₄₂	<i>a</i> ₄₃	<i>a</i> ₄₄	<i>a</i> ₄₅	<i>a</i> ₄₆	<i>a</i> ₄₇	<i>a</i> ₄₈	<i>a</i> ₄₉	a_{50}
a_{31}	a_{32}	<i>a</i> ₃₃	a ₃₄	<i>a</i> ₃₅	<i>a</i> ₃₆	a ₃₇	a_{38}	<i>a</i> ₃₉	a_{40}
a_{21}	<i>a</i> ₂₂	<i>a</i> ₂₃	<i>a</i> ₂₄	a_{25}	a_{26}	a ₂₇	a_{28}	<i>a</i> ₂₉	a_{30}
a_{11}	a_{12}	a_{13}	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	<i>a</i> ₁₉	a_{20}
$a_{\rm l}$	a_2	<i>a</i> ₃	a_4	a ₅ _	a_6	a_7	a_8	a_9	a_{10}

 $a_1 + a_2 + a_3 + a_{12} = 0$



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 a_{91} a_{92} a_{93} a_{94} a_{05} a_{96} a₉₇ a_{98} a₉₉ a_{100} a_{84} a_{81} a_{82} a_{83} a_{85} a_{86} a_{87} a_{88} \mathcal{A}_{89} a_{00} a_{71} a_{72} a_{73} a_{74} a_{75} a_{76} a_{77} a_{78} a_{79} a_{80} a_{64} a_{61} a_{62} a_{63} a_{65} a_{66} a_{67} a_{68} a_{60} a_{70} a_{51} a_{52} a_{53} a_{54} a_{55} a_{56} a_{57} a_{58} a_{59} a_{60} ᠬ a_{43} a_{41} a_{42} a_{44} a_{45} a_{46} a_{47} a_{48} a_{49} a_{50} a_{31} a_{33} a_{32} a_{34} a_{35} a_{36} a_{37} a_{38} a_{39} a_{40} a_{21} a_{22} a_{23} a_{24} a_{25} a_{26} a_{27} a_{28} a_{29} a_{30} a_{15} a_{16} a_{11} a_{13} a_{14} a_{17} a_{18} a_{19} a_{20} $a_{\scriptscriptstyle A}$ $a_{\rm s}$ a_6 a_7 a_8 a_0 a_{10}

$a_1 + a_2 + a_3 + a_{12} = 0$
$a_2 + a_3 + a_4 + a_{13} = 0$
$a_3 + a_4 + a_5 + a_{14} = 0$
$a_4 + a_5 + a_6 + a_{15} = 0$
$a_5 + a_6 + a_7 + a_{16} = 0$
$a_6 + a_7 + a_8 + a_{17} = 0$
$a_7 + a_8 + a_9 + a_{18} = 0$
$a_8 + a_9 + a_{10} + a_{19} = 0$
$a_9 + a_{10} + a_1 + a_{20} = 0$
$a_{10} + a_1 + a_2 + a_{11} = 0$

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c>c>												
a_{91}	$a_{\!_{92}}$	a_{93}	a ₉₄	a_{95}	$a_{\!_{96}}$	a ₉₇	$a_{\!_{98}}$	a ₉₉	a_{100}			
$a_{\!_{81}}$	$a_{\!_{82}}$	a ₈₃	$a_{\!_{84}}$	a_{85}	$a_{\!_{86}}$	a ₈₇	$a_{\!_{88}}$	a ₈₉	a_{90}			
<i>a</i> ₇₁	<i>a</i> ₇₂	<i>a</i> ₇₃	<i>a</i> ₇₄	a ₇₅	a_{76}	<i>a</i> ₇₇	a_{78}	a_{79}	$a_{\!_{80}}$			
a_{61}	<i>a</i> ₆₂	<i>a</i> ₆₃	<i>a</i> ₆₄	a ₆₅	a ₆₆	a ₆₇	<i>a</i> ₆₈	a ₆₉	a_{70}			
<i>a</i> ₅₁	<i>a</i> ₅₂	a ₅₃	<i>a</i> ₅₄	a ₅₅	a ₅₆	a ₅₇	a ₅₈	a ₅₉	a_{60}			
a ₄₁	<i>a</i> ₄₂	<i>a</i> ₄₃	<i>a</i> ₄₄	<i>a</i> ₄₅	a_{46}	<i>a</i> ₄₇	$a_{\!$	a_{49}	a_{50}			
<i>a</i> ₃₁	a_{32}	<i>a</i> ₃₃	<i>a</i> ₃₄	a ₃₅	a_{36}	a ₃₇	a_{38}	a_{39}	a_{40}			
a_{21}	<i>a</i> ₂₂	<i>a</i> ₂₃	<i>a</i> ₂₄	a ₂₅	a_{26}	a ₂₇	a_{28}	a_{29}	a_{30}			
a_{11}	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	a_{19}	a_{20}			
a_{l}	a_2	a_3	a_4	a5 ,	a_6	a_7	a_8	a_9	a_{10}			
	$ \begin{array}{c} a_{81} \\ a_{71} \\ a_{61} \\ a_{6$	$\begin{array}{c c} a_{81} & a_{82} \\ a_{71} & a_{72} \\ a_{61} & a_{62} \\ a_{51} & a_{52} \\ a_{41} & a_{42} \\ a_{31} & a_{32} \\ a_{21} & a_{22} \\ a_{11} & a_{12} \end{array}$	$\begin{array}{c cccc} a_{81} & a_{82} & a_{83} \\ a_{71} & a_{72} & a_{73} \\ a_{61} & a_{62} & a_{63} \\ a_{51} & a_{52} & a_{53} \\ a_{41} & a_{42} & a_{43} \\ a_{31} & a_{32} & a_{33} \\ a_{21} & a_{22} & a_{23} \\ a_{41} & a_{42} & a_{43} \\ \end{array}$	$\begin{array}{c ccccc} a_{81} & a_{82} & a_{83} & a_{84} \\ a_{71} & a_{72} & a_{73} & a_{74} \\ a_{61} & a_{62} & a_{63} & a_{64} \\ a_{51} & a_{52} & a_{53} & a_{54} \\ a_{41} & a_{42} & a_{43} & a_{44} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{41} & a_{42} & a_{43} & a_{44} \\ \end{array}$	$\begin{array}{c ccccc} a_{81} & a_{82} & a_{83} & a_{84} & a_{85} \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$			

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a_{91}									
21	a_{92}	a_{93}	$a_{\!94}$	a_{95}	a_{96}	a ₉₇	$a_{\!_{98}}$	a ₉₉	a_{100}
a_{81}	$a_{\!_{82}}$	a ₈₃	$a_{\!_{84}}$	a_{85}	$a_{\!_{86}}$	$a_{\!_{87}}$	$a_{\!_{88}}$	$a_{\!_{89}}$	$a_{\!90}$
a_{71}	a ₇₂	a ₇₃	<i>a</i> ₇₄	a ₇₅	a_{76}	a ₇₇	a_{78}	a_{79}	$a_{\!80}$
a_{61}	$a_{\!62}$	<i>a</i> ₆₃	$a_{\!64}$	a ₆₅	a ₆₆	a ₆₇	$a_{\!_{68}}$	a ₆₉	a_{70}
a_{51}	<i>a</i> ₅₂	a ₅₃	<i>a</i> ₅₄	a ₅₅	a ₅₆	a ₅₇	a ₅₈	a ₅₉	a ₆₀
a ₄₁	a_{42}	<i>a</i> ₄₃	<i>a</i> ₄₄	<i>a</i> ₄₅	a_{46}	<i>a</i> ₄₇	$a_{\!$	$a_{\!$	а ₅₀
<i>a</i> ₃₁	<i>a</i> ₃₂	<i>a</i> ₃₃	a ₃₄	a ₃₅	a ₃₆	a ₃₇	a_{38}	a ₃₉	a_{40}
a_{21}	<i>a</i> ₂₂	a ₂₃	a ₂₄	a ₂₅	a_{26}	a ₂₇	a_{28}	a_{29}	a_{30}
a_{11}	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	a_{19}	a_{20}
a_{l}	<i>a</i> ₂	a_3	a_4	<i>a</i> 5	a_6	<i>a</i> ₇	a_8	a_9	a_{10}
	$ \begin{array}{c} a_{71} \\ a_{61} \\ a_{51} \\ a_{41} \\ a_{31} \\ a_{21} \\ a_{11} \\ \end{array} $	$\begin{array}{c cccc} a_{71} & a_{72} \\ a_{61} & a_{62} \\ a_{51} & a_{52} \\ a_{41} & a_{42} \\ a_{31} & a_{32} \\ a_{21} & a_{22} \\ a_{11} & a_{12} \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

$a_{11} + a_{12} + a_{13} + a_2 = 0$	
$a_{12} + a_{13} + a_{14} + a_3 = 0$	
$a_{13} + a_{14} + a_{15} + a_4 = 0$	
$a_{14} + a_{15} + a_{16} + a_5 = 0$	
$a_{15} + a_{16} + a_{17} + a_6 = 0$	
$a_{16} + a_{17} + a_{18} + a_7 = 0$	
$a_{17} + a_{18} + a_{19} + a_8 = 0$	
$a_{18} + a_{19} + a_{20} + a_{9} = 0$	
$a_{19} + a_{20} + a_{11} + a_{10} = 0$	
$a_{20} + a_{11} + a_{12} + a_1 = 0$	

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			<u> </u>	\rightarrow				
a_{92}	a_{93}	a ₉₄	a_{95}	a_{96}	a ₉₇	$a_{\!_{98}}$	a ₉₉	a_{100}
$a_{\!82}$	a ₈₃	$a_{\!_{84}}$	a_{85}	a_{86}	a ₈₇	$a_{\!_{88}}$	a ₈₉	$a_{\!_{90}}$
<i>a</i> ₇₂	<i>a</i> ₇₃	<i>a</i> ₇₄	a ₇₅	a_{76}	<i>a</i> ₇₇	a_{78}	a_{79}	$a_{\!_{80}}$
a_{62}	a ₆₃	$a_{\!64}$	a_{65}	a_{66}	a ₆₇	a ₆₈	a ₆₉	a_{70}
<i>a</i> ₅₂	a ₅₃	<i>a</i> ₅₄	a ₅₅	a_{56}	a ₅₇	a ₅₈	a ₅₉	a_{60}
<i>a</i> ₄₂	<i>a</i> ₄₃	<i>a</i> ₄₄	<i>a</i> ₄₅	$a_{\!$	a ₄₇	<i>a</i> ₄₈	a ₄₉	a_{50}
a_{32}	<i>a</i> ₃₃	<i>a</i> ₃₄	<i>a</i> ₃₅	a_{36}	a ₃₇	a_{38}	a_{39}	a_{40}
<i>a</i> ₂₂	<i>a</i> ₂₃	<i>a</i> ₂₄	a ₂₅	a_{26}	a ₂₇	a_{28}	a_{29}	a_{30}
a_{12}	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	a_{19}	a_{20}
a_2	a_3	a_4	a ₅ _	a_6	a_7	a_8	a_9	a_{10}
	$egin{aligned} a_{82} & a_{72} \ a_{62} & a_{52} \ a_{42} & a_{32} \ a_{22} & a_{12} \end{aligned}$	$\begin{array}{cccc} a_{82} & a_{83} \\ a_{72} & a_{73} \\ a_{62} & a_{63} \\ a_{52} & a_{53} \\ a_{42} & a_{43} \\ a_{32} & a_{33} \\ a_{22} & a_{23} \\ a_{12} & a_{13} \end{array}$	$\begin{array}{cccc} a_{82} & a_{83} & a_{84} \\ a_{72} & a_{73} & a_{74} \\ a_{62} & a_{63} & a_{64} \\ a_{52} & a_{53} & a_{54} \\ a_{42} & a_{43} & a_{44} \\ a_{32} & a_{33} & a_{34} \\ a_{22} & a_{23} & a_{24} \\ a_{12} & a_{13} & a_{14} \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c cccccc} a_{82} & a_{83} & a_{84} & a_{85} & a_{86} \\ \hline a_{72} & a_{73} & a_{74} & a_{75} & a_{76} \\ \hline a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \\ \hline a_{52} & a_{53} & a_{54} & a_{55} & a_{56} \\ \hline a_{42} & a_{43} & a_{44} & a_{45} & a_{46} \\ \hline a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\ \hline a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ \hline a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

$a_{11} + a_{12} + a_{13} + a_2 = 0$
$a_{12} + a_{13} + a_{14} + a_3 = 0$
$a_{13} + a_{14} + a_{15} + a_4 = 0$
$a_{14} + a_{15} + a_{16} + a_5 = 0$
$a_{15} + a_{16} + a_{17} + a_6 = 0$
$a_{16} + a_{17} + a_{18} + a_7 = 0$
$a_{17} + a_{18} + a_{19} + a_8 = 0$
$a_{18} + a_{19} + a_{20} + a_{9} = 0$
$a_{19} + a_{20} + a_{11} + a_{10} = 0$
$a_{20} + a_{11} + a_{12} + a_1 = 0$

 $a_{11} + a_{12} + a_{13} + a_2 = 0$

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			<u> </u>	\rightarrow				
a_{92}	a_{93}	a ₉₄	a_{95}	a_{96}	a ₉₇	$a_{\!_{98}}$	a ₉₉	a_{100}
$a_{\!82}$	a ₈₃	$a_{\!_{84}}$	a_{85}	a_{86}	a ₈₇	$a_{\!_{88}}$	a ₈₉	$a_{\!_{90}}$
<i>a</i> ₇₂	<i>a</i> ₇₃	<i>a</i> ₇₄	<i>a</i> ₇₅	a_{76}	<i>a</i> ₇₇	a_{78}	a_{79}	$a_{\!_{80}}$
a_{62}	a ₆₃	$a_{\!64}$	a_{65}	a_{66}	a ₆₇	a ₆₈	a ₆₉	a_{70}
<i>a</i> ₅₂	a ₅₃	<i>a</i> ₅₄	a ₅₅	a_{56}	a ₅₇	a ₅₈	a ₅₉	a_{60}
<i>a</i> ₄₂	<i>a</i> ₄₃	<i>a</i> ₄₄	<i>a</i> ₄₅	<i>a</i> ₄₆	a ₄₇	$a_{\!48}$	a ₄₉	a_{50}
a_{32}	<i>a</i> ₃₃	<i>a</i> ₃₄	<i>a</i> ₃₅	a_{36}	a ₃₇	a_{38}	a_{39}	a_{40}
<i>a</i> ₂₂	<i>a</i> ₂₃	<i>a</i> ₂₄	a ₂₅	a_{26}	a ₂₇	a_{28}	a_{29}	a_{30}
a_{12}	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	a_{19}	a_{20}
a_2	a_3	a_4	a ₅ _	a_6	a_7	a_8	a_9	a_{10}
	$egin{aligned} a_{82} & a_{72} \ a_{62} & a_{52} \ a_{42} & a_{32} \ a_{22} & a_{12} \end{aligned}$	$\begin{array}{cccc} a_{82} & a_{83} \\ a_{72} & a_{73} \\ a_{62} & a_{63} \\ a_{52} & a_{53} \\ a_{42} & a_{43} \\ a_{32} & a_{33} \\ a_{22} & a_{23} \\ a_{12} & a_{13} \end{array}$	$\begin{array}{cccc} a_{82} & a_{83} & a_{84} \\ a_{72} & a_{73} & a_{74} \\ a_{62} & a_{63} & a_{64} \\ a_{52} & a_{53} & a_{54} \\ a_{42} & a_{43} & a_{44} \\ a_{32} & a_{33} & a_{34} \\ a_{22} & a_{23} & a_{24} \\ a_{12} & a_{13} & a_{14} \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{c cccccc} a_{82} & a_{83} & a_{84} & a_{85} & a_{86} \\ \hline a_{72} & a_{73} & a_{74} & a_{75} & a_{76} \\ \hline a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \\ \hline a_{52} & a_{53} & a_{54} & a_{55} & a_{56} \\ \hline a_{42} & a_{43} & a_{44} & a_{45} & a_{46} \\ \hline a_{32} & a_{33} & a_{34} & a_{35} & a_{36} \\ \hline a_{22} & a_{23} & a_{24} & a_{25} & a_{26} \\ \hline a_{12} & a_{13} & a_{14} & a_{15} & a_{16} \end{array}$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

$a_{11} + a_{12} + a_{13} + a_2 = 0$
$a_{12} + a_{13} + a_{14} + a_3 = 0$
$a_{13} + a_{14} + a_{15} + a_4 = 0$
$a_{14} + a_{15} + a_{16} + a_5 = 0$
$a_{15} + a_{16} + a_{17} + a_6 = 0$
$a_{16} + a_{17} + a_{18} + a_7 = 0$
$a_{17} + a_{18} + a_{19} + a_8 = 0$
$a_{18} + a_{19} + a_{20} + a_{9} = 0$
$a_{19} + a_{20} + a_{11} + a_{10} = 0$
$a_{20} + a_{11} + a_{12} + a_1 = 0$

$$a_{11} + a_{12} + a_{13} + a_2 = 0$$

$$a_{11} + a_{12} + a_{13} + a_{22} = 0$$

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					<u></u>	\rightarrow				
	<i>a</i> ₉₁	a_{92}	a_{93}	a ₉₄	a_{95}	a_{96}	a ₉₇	$a_{\!_{98}}$	a ₉₉	a_{100}
	a_{81}	$a_{\!_{82}}$	a_{83}	$a_{\!_{84}}$	$a_{\!_{85}}$	$a_{\!_{86}}$	$a_{\!_{87}}$	$a_{\!_{88}}$	$a_{\!89}$	$a_{\!90}$
ſ	<i>a</i> ₇₁	<i>a</i> ₇₂	<i>a</i> ₇₃	<i>a</i> ₇₄	<i>a</i> ₇₅	a_{76}	<i>a</i> ₇₇	a_{78}	a_{79}	$a_{\!_{80}}$
ĺ	a_{61}	a_{62}	<i>a</i> ₆₃	<i>a</i> ₆₄	a ₆₅	a ₆₆	a ₆₇	<i>a</i> ₆₈	a ₆₉	a_{70}
ĺ	<i>a</i> ₅₁	<i>a</i> ₅₂	a ₅₃	<i>a</i> ₅₄	a ₅₅	a ₅₆	a ₅₇	a ₅₈	a ₅₉	a_{60}
l	a ₄₁	<i>a</i> ₄₂	<i>a</i> ₄₃	<i>a</i> ₄₄	<i>a</i> ₄₅	a_{46}	<i>a</i> ₄₇	$a_{\!$	a_{49}	a_{50}
	<i>a</i> ₃₁	<i>a</i> ₃₂	a ₃₃	a ₃₄	a ₃₅	a ₃₆	a ₃₇	a ₃₈	<i>a</i> ₃₉	a_{40}
	a_{21}	<i>a</i> ₂₂	<i>a</i> ₂₃	<i>a</i> ₂₄	a ₂₅	a_{26}	a ₂₇	a_{28}	a_{29}	a_{30}
	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	a_{19}	a_{20}
ſ	a_{l}	a_2	a_3	a_4	a ₅ _	a_6	a_7	a_8	a_9	a_{10}

$a_{11} + a_{12} + a_{13} + a_2 = 0$
$a_{12} + a_{13} + a_{14} + a_3 = 0$
$a_{13} + a_{14} + a_{15} + a_4 = 0$
$a_{14} + a_{15} + a_{16} + a_5 = 0$
$a_{15} + a_{16} + a_{17} + a_6 = 0$
$a_{16} + a_{17} + a_{18} + a_7 = 0$
$a_{17} + a_{18} + a_{19} + a_8 = 0$
$a_{18} + a_{19} + a_{20} + a_{9} = 0$
$a_{19} + a_{20} + a_{11} + a_{10} = 0$
$a_{20} + a_{11} + a_{12} + a_1 = 0$

$$a_{11} + a_{12} + a_{13} + a_2 = 0$$
$$a_{11} + a_{12} + a_{13} + a_{22} = 0$$
$$a_{2} = a_{22}$$

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$a_1 = a_3 = a_5 = a_7 = a_9 = a_{12} = a_{14} = a_{16} = a_{18} = a_{20}$ $a_2 = a_6 = a_8 = a_{10} = a_{11} = a_{13} = a_{15} = a_{17} = a_{19}$

iling problem:

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$$a_1 = a_3 = a_5 = a_7 = a_9 = a_{12} = a_{14} = a_{16} = a_{18} = a_{20}$$

 $a_2 = a_6 = a_8 = a_{10} = a_{11} = a_{13} = a_{15} = a_{17} = a_{19}$

Analogue

 $a_{21} = a_{23} = a_{25} = a_{27} = a_{29} = a_{32} = a_{34} = a_{36} = a_{38} = a_{40}$ $a_{41} = a_{43} = a_{45} = a_{47} = a_{49} = a_{42} = a_{44} = a_{46} = a_{48} = a_{60}$ $a_{61} = a_{63} = a_{65} = a_{67} = a_{69} = a_{62} = a_{64} = a_{66} = a_{68} = a_{80}$ $a_{81} = a_{83} = a_{85} = a_{87} = a_{89} = a_{82} = a_{84} = a_{86} = a_{88} = a_{100}$ $a_{22} = a_{24} = a_{26} = a_{28} = a_{30} = a_{31} = a_{33} = a_{35} = a_{37} = a_{39}$ $a_{42} = a_{44} = a_{46} = a_{48} = a_{50} = a_{51} = a_{53} = a_{55} = a_{57} = a_{59}$ $a_{62} = a_{64} = a_{66} = a_{68} = a_{70} = a_{71} = a_{73} = a_{75} = a_{77} = a_{79}$ $a_{82} = a_{84} = a_{86} = a_{88} = a_{90} = a_{91} = a_{93} = a_{95} = a_{97} = a_{99}$

Homology groups of generalized polyomino type tilings Edin Liđan Polyomino Tilings with Homology groups of generalized polyomino type tillings



						<u> </u>				
	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
١	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_{l}	a_2	a_{l}	a_2
	a_2	a_1	a_2	a_1	a_2	a_{l}	a_2	a_1	a_2	a_1
	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
	a_2	a_1	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_1
	a_1	a_2	a_1	a_2	a, ,	a_2	a_1	a_2	a_1	a_2

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					<u> </u>				
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2

$$3a_1 + a_2 = 0$$

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					<u> </u>				
a_2	a_{1}	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_{l}	a_2	a_{l}	a_2	a_{1}	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_{l}	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2

$3a_1 + a_2$	=	0
$3a_2 + a_1$	=	0

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					<u> </u>				
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_{1}
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_{1}	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2

- $3a_1 + a_2 = 0$ $3a_2 + a_1 = 0$
- $0a_2 + a_1 = 0$

$$\bullet < a_1, a_2|_{3a_1+a_2, 3a_2+a_1} >$$

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					<u> </u>				
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_{1}	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_{l}	a_2	a_1
a_1	a_2	a_1	a_2	a ₁	a_2	a_1	a_2	a_1	a_2

- $3a_1 + a_2 = 0$ $3a_2 + a_1 = 0$

$$\bullet < a_1, a_2|_{3a_1+a_2, 3a_2+a_1} >$$

► =<
$$a_1|_{8a_1=0}$$
 >= \mathbb{Z}_8

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					<u> </u>				
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_{1}
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1
$\begin{bmatrix} a_1 \end{bmatrix}$	a_2	a_1	a_2	a_{l}	a_2	a_{l}	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_{l}	a_2	a_{1}	a_2	a_1
a_1	a_2	a_1	a_2	a_{1}	a_2	a_{l}	a_2	a_1	a_2
a_2	a_1	a_2	a_1	a_2	a_{l}	a_2	a_{l}	a_2	a_1
a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2	a_1	a_2

- $3a_1 + a_2 = 0$ $3a_2 + a_1 = 0$

►
$$< a_1, a_2|_{3a_1+a_2, 3a_2+a_1} >$$

► $= < a_1|_{8a_1=0} > = \mathbb{Z}_8$

$$50a_1 + 50a_2 = -100a_1 = 4a_1$$

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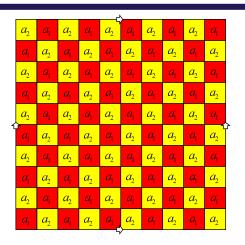
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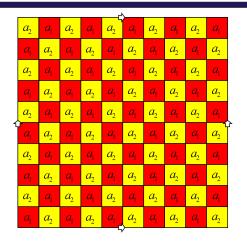
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50 red cells

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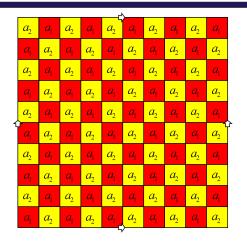
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- 50 red cells
- ► 50 yellow cells

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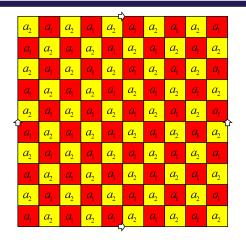
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- ▶ 50 red cells
- ► 50 yellow cells
- every T tetramino cover

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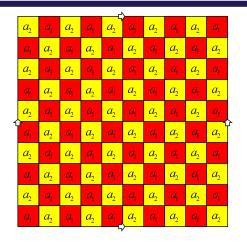
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50 red cells

- ► 50 yellow cells
- every T tetramino cover
 - 3 red and 1 yellow

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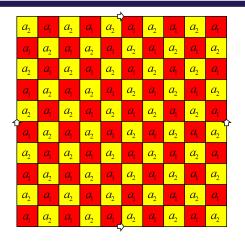
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50 red cells

- ► 50 yellow cells
- every T tetramino cover
 - 3 red and 1 yellow
 - 3 yellow and 1 red

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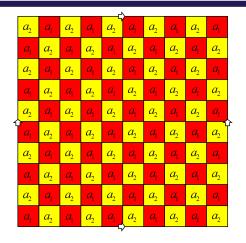
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50 red cells

- ► 50 yellow cells
- every T tetramino cover
 - 3 red and 1 yellow
 - 3 yellow and 1 red

tiling is not possible

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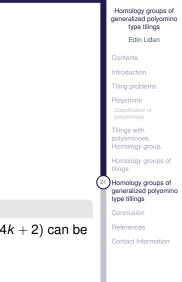
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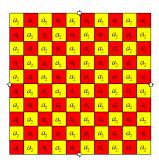
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Theorem

The torus chessboard of dimension $(4k + 2) \times (4k + 2)$ can be not tiling with T – tetrominoes.



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Example

Is it possible to tile torus chessboard 9×5 with one removed cell in the middle to tile with square shapes 2×2 and cross shape (all orientation are allowed)?

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Example

Is it possible to tile torus chessboard 9×5 with one removed cell in the middle to tile with square shapes 2×2 and cross shape (all orientation are allowed)?





Example

Is it possible to tile torus chessboard 9×5 with one removed cell in the middle to tile with square shapes 2×2 and cross shape (all orientation are allowed)?



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Example

Is it possible to tile torus chessboard 9×5 with one removed cell in the middle to tile with square shapes 2×2 and cross shape (all orientation are allowed)?

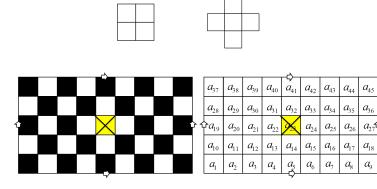


Figure: In torus plane model

Figure: Naming cell



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					^					
	a ₃₇	a_{38}	<i>a</i> ₃₉	a_{40}	a_{41}	<i>a</i> ₄₂	<i>a</i> ₄₃	<i>a</i> ₄₄	a ₄₅	
	a_{28}	a_{29}	<i>a</i> ₃₀	<i>a</i> ₃₁	a_{32}	<i>a</i> ₃₃	<i>a</i> ₃₄	<i>a</i> ₃₅	a ₃₆	
٦	a_{19}	a_{20}	a_{21}	<i>a</i> ₂₂	X	a_{24}	<i>a</i> ₂₅	a_{26}	a27	ł
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	a_{17}	a_{18}	
	a_{l}	a_2	a_3	a_4	a _s	a_6	a_7	a_8	a_9	

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					^					
	a ₃₇	a_{38}	<i>a</i> ₃₉	a_{40}	a_{41}	$a_{\!_{42}}$	<i>a</i> ₄₃	a_{44}	<i>a</i> ₄₅	
	a_{28}	a_{29}	<i>a</i> ₃₀	<i>a</i> ₃₁	a_{32}	<i>a</i> ₃₃	<i>a</i> ₃₄	<i>a</i> ₃₅	a ₃₆	
٦	a_{19}	a_{20}	a_{21}	<i>a</i> ₂₂	X	a_{24}	<i>a</i> ₂₅	a_{26}	a27	ł
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	a_{17}	a_{18}	
	a_{1}	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	
	· · · · · · · · · · · · · · · · · · ·				-4-					•

 $a_1 + a_2 + a_{10} + a_{11} = 0$

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					^					
	a ₃₇	a_{38}	<i>a</i> ₃₉	a_{40}	a_{41}	a_{42}	a_{43}	<i>a</i> ₄₄	<i>a</i> ₄₅	
	a_{28}	a_{29}	<i>a</i> ₃₀			<i>a</i> ₃₃		<i>a</i> ₃₅	<i>a</i> ₃₆	
í	a_{19}	a_{20}	<i>a</i> ₂₁	<i>a</i> ₂₂	X	<i>a</i> ₂₄	<i>a</i> ₂₅	a_{26}	a27	ļ
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	
	a_{1}	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	
	· · · · · · · · · · · · · · · · · · ·				-4-					

 $a_1 + a_2 + a_{10} + a_{11} = 0$ $a_{21} + a_{30} + a_{22} + a_{31} = 0$ Homology groups of generalized polyomino type tilings

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					^					
	a ₃₇	a_{38}	<i>a</i> ₃₉	a_{40}	a_{41}	a_{42}	a_{43}	<i>a</i> ₄₄	<i>a</i> ₄₅	
	a_{28}	a29	<i>a</i> ₃₀	a_{31}	a_{32}	<i>a</i> ₃₃	<i>a</i> ₃₄	<i>a</i> ₃₅	<i>a</i> ₃₆	
í	a_{19}	a_{20}	a_{21}	<i>a</i> ₂₂	X	<i>a</i> ₂₄	a25	a_{26}	a27	ļ
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	
	a_{1}	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	
					-y-					•

 a_{37} a_{42} a_{38} $a_{39} \mid a_{40}$ a_{41} a_{43} a_{44} a_{45} a_{28} a_{29} a_{30} a_{31} a_{32} a_{33} a_{24} a_{35} a_{36} a24 $\mathcal{C}a_{19}$ a_{21} an a_{25} a_{26} a279 a_{13} a_{14} a_{15} a_{16} a_{17} a_{18} a_{2} $a_{\rm s}$ a_6 a_7 a_8 a_{0} a_1 $a_{\scriptscriptstyle A}$

 $a_1 + a_2 + a_{10} + a_{11} = 0$ $a_{21} + a_{30} + a_{22} + a_{31} = 0$



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					^				
	a ₃₇	a_{38}	<i>a</i> ₃₉	a_{40}	a_{41}	$a_{\!_{42}}$	a_{43}	a_{44}	a_{45}
	a_{28}	a_{29}	<i>a</i> ₃₀	<i>a</i> ₃₁	a_{32}	<i>a</i> ₃₃	<i>a</i> ₃₄	<i>a</i> ₃₅	<i>a</i> ₃₆
4	a_{19}	a_{20}	a_{21}	<i>a</i> ₂₂	X	a_{24}	a_{25}	a_{26}	a27
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}
	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9
		_			<u>ч</u> у–				

	a37	a_{38}	<i>a</i> ₃₉	a_{40}	a_{41}	<i>a</i> ₄₂	a_{43}	<i>a</i> ₄₄	a_{45}	
	an	a	a30	a	a ₃₂	ч2 a ₃₃	a ₃₄	a.,		
J	u ₂₈	<i>u</i> ₂₉	<i>u</i> ₃₀	<i>u</i> ₃₁	\sim		<i>u</i> ₃₄	<i>u</i> ₃₅	<i>u</i> ₃₆	l
٦	$-a_{19}$	a_{20}	a_{21}	a_{22}	<u>×</u>	<i>a</i> ₂₄	u_{25}	u_{26}	<i>a</i> ₂₇	ſ
	a_{10}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	
	a_{1}	a_2	a_3	a_4	a _s	a_6	a_7	a_8	a_9	

x

$$a_1 + a_2 + a_{10} + a_{11} = 0$$
$$a_{21} + a_{30} + a_{22} + a_{31} = 0$$

$$a_{20} + a_{10} + a_{11} + a_{12} + a_2 = 0$$



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					<u>~~</u>				
	a ₃₇	a_{38}	a ₃₉	a_{40}	a_{41}	<i>a</i> ₄₂	a ₄₃	$a_{\!$	<i>a</i> ₄₅
	a_{28}	a_{29}	<i>a</i> ₃₀	<i>a</i> ₃₁	<i>a</i> ₃₂	a ₃₃	a ₃₄	a35	a_{36}
4	a_{19}	<i>a</i> ₂₀	<i>a</i> ₂₁	<i>a</i> ₂₂	\times	a_{24}	<i>a</i> ₂₅	a_{26}	a27
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	a_{17}	a_{18}
	$a_{\rm l}$	a_2	<i>a</i> ₃	a_4	a_{5}	a_6	a_7	$a_{\!_8}$	a_9

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					^				
	a ₃₇	a_{38}	<i>a</i> ₃₉	$a_{\!$	a_{41}	a_{42}	<i>a</i> ₄₃	a ₄₄	<i>a</i> ₄₅
	a_{28}	a_{29}	<i>a</i> ₃₀	<i>a</i> ₃₁	<i>a</i> ₃₂	<i>a</i> ₃₃	<i>a</i> ₃₄	a35	a_{36}
{	a_{19}	<i>a</i> ₂₀	<i>a</i> ₂₁	<i>a</i> ₂₂	X	a_{24}	<i>a</i> ₂₅	a_{26}	a27
	a_{10}	<i>a</i> ₁₁	a_{12}	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}
	$a_{\rm l}$	a_2	a_3	a_4	a ₅	a_6	a_7	a_8	a_9

$a_{12} + a_{20} + a_{21} + a_{22} + a_{30} = 0$

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					^				
	a ₃₇	a_{38}	a_{39}	$a_{\!$	a_{41}	$a_{\!_{42}}$	$a_{\!_{43}}$	<i>a</i> ₄₄	<i>a</i> ₄₅
	a_{28}	a_{29}	<i>a</i> ₃₀	<i>a</i> ₃₁	<i>a</i> ₃₂	<i>a</i> ₃₃	a ₃₄	a35	a_{36}
{	a_{19}	<i>a</i> ₂₀	<i>a</i> ₂₁	<i>a</i> ₂₂	X	<i>a</i> ₂₄	<i>a</i> ₂₅	a_{26}	a27
	a_{10}	<i>a</i> ₁₁	a_{12}	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	a_{17}	a_{18}
	a_1	a_2	a_3	a_4	a ₅	a_6	<i>a</i> ₇	a_8	a_9

$$a_{12} + a_{20} + a_{21} + a_{22} + a_{30} = 0$$

					<u>~~</u>				
	a ₃₇	a_{38}	<i>a</i> ₃₉	a_{40}	a_{41}	$a_{\!_{42}}$	$a_{\!_{43}}$	$a_{\!\scriptscriptstyle 44}$	a_{45}
	a_{28}	a_{29}	<i>a</i> ₃₀	a_{31}	<i>a</i> ₃₂	<i>a</i> ₃₃	<i>a</i> ₃₄	<i>a</i> ₃₅	<i>a</i> ₃₆
ł	•a ₁₉	a_{20}	<i>a</i> ₂₁	<i>a</i> ₂₂	X	a_{24}	<i>a</i> ₂₅	a_{26}	a27
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	<i>a</i> ₁₄	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}
(a_1	a_2	<i>a</i> ₃	a_4	a _s	a_6	a_7	a_8	a_9

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					^`					
	a ₃₇	a_{38}	a_{39}	a_{40}	a_{41}	$a_{\!_{42}}$	$a_{\!_{43}}$	$a_{\!$	a_{45}	
	a_{28}	a_{29}	<i>a</i> ₃₀	<i>a</i> ₃₁	<i>a</i> ₃₂	<i>a</i> ₃₃	<i>a</i> ₃₄	a ₃₅	<i>a</i> ₃₆	
{	a_{19}	<i>a</i> ₂₀	<i>a</i> ₂₁	a ₂₂	X	<i>a</i> ₂₄	<i>a</i> ₂₅	a_{26}	a27	ł
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	
	a_{1}	a_2	a_3	a_4	a ₅	a_6	<i>a</i> ₇	$a_{\!\scriptscriptstyle 8}$	a_9	

$$a_{12} + a_{20} + a_{21} + a_{22} + a_{30} = 0$$

 $a_1 = a_{31}$

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$a_{43} a_{44} $	
43 0444	<i>a</i> ₄₅
$a_{34} a_{35}$	<i>a</i> ₃₆
$a_{25} a_{26}$	a27
$a_{16} a_{17} $	a_{18}
$a_7 a_8$	<i>a</i> ₉
	$\begin{array}{c ccc} a_{34} & a_{35} \\ \hline a_{25} & a_{26} \\ \hline a_{16} & a_{17} \end{array}$

$$a_{12} + a_{20} + a_{21} + a_{22} + a_{30} = 0$$

					<u>~~</u>					
	a ₃₇	a_{38}	<i>a</i> ₃₉	$a_{\!40}$	a_{41}	$a_{\!_{42}}$	$a_{\!_{43}}$	$a_{\!$	<i>a</i> ₄₅	
	a_{28}	a29	<i>a</i> ₃₀	(a ₃₁)	<i>a</i> ₃₂	<i>a</i> ₃₃	a ₃₄	a35	a36	
٢	a_{19}	a_{20}	<i>a</i> ₂₁	<i>a</i> ₂₂	X	a_{24}	<i>a</i> ₂₅	a_{26}	a27	ļ
	a_{10}	<i>a</i> ₁₁	<i>a</i> ₁₂	<i>a</i> ₁₃	a_{14}	<i>a</i> ₁₅	a_{16}	<i>a</i> ₁₇	a_{18}	
	(a_1)	a_2	<i>a</i> ₃	a_4	a _s	a_6	<i>a</i> ₇	a_8	a_9	

$$a_1 = a_3$$

Analogue

$$a_{31} = a_{16} = a_{37} = a_{22}$$

 $a_1 = a_{34} = a_{10} = a_{40} = a_{25}$
 $a_{37} = a_{13} = a_{28}$
 $a_{28} = a_4 = a_{19} = a_{43}$
 $a_{28} = a_7$

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					^					
	a_1	a_{38}	a_{39}	a_{1}	a_{41}	a_{42}	a_{1}	<i>a</i> ₄₄	a_{45}	
	a_1	<i>a</i> ₂₉	<i>a</i> ₃₀	a_{1}	<i>a</i> ₃₂	<i>a</i> ₃₃	a_{l}	a ₃₅	<i>a</i> ₃₆	
٤	a_1	a_{20}	a_{21}	a_1	х	<i>a</i> ₂₄	a_1	a_{26}	a277	ļ
	a_1	<i>a</i> ₁₁	<i>a</i> ₁₂	a_{l}	a_{14}	<i>a</i> ₁₅	a_{l}	<i>a</i> ₁₇	a_{18}	
	a_1	a_2	a_3	a_1	a_{5}	a_6	a_1	a_8	a_9	
										1

Figure: Cells generated with a1

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					_^					
	a_1	a_{38}	a_{39}	a_{1}	a_{41}	a_{42}	a_{1}	<i>a</i> ₄₄	a_{45}	
	a_1	<i>a</i> ₂₉	a_{30}	a_{1}	<i>a</i> ₃₂	<i>a</i> ₃₃	a_{l}	<i>a</i> ₃₅	<i>a</i> ₃₆	
í	a_1	a_{20}	a_{21}	a_1	х	<i>a</i> ₂₄	a_1	<i>a</i> ₂₆	a277	ļ T
	a_1	<i>a</i> ₁₁	<i>a</i> ₁₂	a_{l}	a_{14}	<i>a</i> ₁₅	a_{l}	<i>a</i> ₁₇	a_{18}	
	a_{1}	a_2	a_3	a_{1}	a_{5}	a_6	a_{1}	a_8	a_9	1

Figure: Cells generated with a1

Analogue

$$a_2 = a_{34} = a_5, a_{34} = a_{11} = a_{41} = a_{26}$$

 $a_{11} = a_{44}, a_{20} = a_5, a_{29} = a_{14} = a_{34}$
 $a_8 = a_{29}, a_{38} = a_{17} = a_{32}, a_{17} = a_{29}$

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5
6
, 存
3
,
2

Figure: Cells generated with a2

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					^					
	a_1	a_2	a_{39}	a_{1}	a_{41}	a_2	a_1	a_2	<i>a</i> ₄₅	
	a_1	a_2	<i>a</i> ₃₀	a_{1}	<i>a</i> ₃₂	a_2	a_{1}	a_2	<i>a</i> ₃₆	
٤	a_1	a_2	a_{21}	a_1	х	a_2	a_{1}	a_2	a274	ł
	a_1	a_2	<i>a</i> ₁₂	a_{l}	a_{14}	a_2	a_{l}	a_2	a_{18}	
	a_1	a_2	a_3	a_1	a_{5}	a_2	a_1	a_2	a_9	

Figure: Cells generated with a2

Analogue

$$a_3 = a_{36} = a_6 = a_{27}$$

 $a_{39} = a_{18} = a_{42} = a_{27}, a_{12} = a_{33}$
 $a_{33} = a_9, a_{21}, a_{24} = a_9, a_{30} = a_{15}$



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					<u> </u>					
	a_1	a_2	<i>a</i> ₃	a_1	a_3	a_2	a_1	a_2	a_3	
	a_{l}	a_2	a_3	a_{1}			-	2	<i>a</i> ₃	
٤	a_1	a_2	a_3	a_1	х	a_2	a_1	a_2	a ₃ 4	ļ ſ
	a_{l}	a_2	<i>a</i> ₃	a_{1}	a_3	a_2	a_{l}	a_2	a_3	
	a_1	a_2	<i>a</i> ₃	a_1		<i>a</i> ₂	a_1	a_2	a_3	

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	a_{1}	a_2	<i>a</i> ₃	a_1	a_3	a_2	a_1	a_2	a_3	
	a_{l}	a_2	a_3	a_{1}	a_3	a_2	a_{l}	a_2	<i>a</i> ₃	
٤	a_1	a_2	a_3	a_1	х	a_2	a_1	a_2	a ₃ 4	ļ
	a_{l}	a_2	<i>a</i> ₃	a_{1}	a_3	a_2	a_{l}	a_2	a_3	
	a_1	a_2	a_3	a_1	a_3	<i>a</i> ₂	a_1	a_2	a_3	
					-~-					

$2a_1 + 2a_2 = 0$	
$2a_2 + 2a_3 = 0$	
$2a_1 + 2a_3 = 0$	

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	a_{1}	a_2	<i>a</i> ₃	a_{1}	a_3	a_2	a_1	a_2	a_3	
	a_{l}	a_2	a_3	$a_{\rm l}$	<i>a</i> ₃	a_2	a_{l}	a_2	a_3	
٤	a_1	a_2	a_3	a_1	х	a_2	a_1	a_2	a ₃ 4	Ļ
	a_{l}	a_2	<i>a</i> ₃	a_{l}	a_3	a_2	a_{l}	a_2	a_3	
	a_1	a_2	<i>a</i> ₃	a_1		a_2	a_1	a_2	a_3	

2a ₁	+	$2a_{2}$	=	0

$$2a_2 + 2a_3 = 0$$

$$2a_1 + 2a_3 = 0$$

$$3a_2 + a_1 + a_3 = 0$$

$$3a_3 + a_1 + a_2 = 0$$

$$3a_1 + a_2 + a_3 = 0$$

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	a_1	a_2	<i>a</i> ₃	a_{1}	a_3	a_2	a_1	a_2	a_3	
	a_{l}	a_2	a_3	a_{l}	<i>a</i> ₃	a_2	a_{l}	a_2	<i>a</i> ₃	
1	a_1	a_2	a_3	a_1	х	a_2	a_1	a_2	a ₃ 4	ļ
	a_{l}	a_2	<i>a</i> ₃	a_{l}	a_3	a_2	a_{l}	a_2	a_3	
	a_1	a_2	a_3	a_1	a_3	<i>a</i> ₂	a_1	a_2	a_3	
					-4-					

$2a_1 + 2a_2 = 0$
$2a_2 + 2a_3 = 0$
$2a_1 + 2a_3 = 0$
$3a_2 + a_1 + a_3 = 0$
$3a_3 + a_1 + a_2 = 0$
$3a_1 + a_2 + a_3 = 0$

Figure: Cells generated with a₃

$$\bullet < a_1, a_2, a_3 | 2a_1 = 2a_2 = 2a_3 = a_1 + a_2 + a_3 = 0 >$$

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	a_{1}	a_2	<i>a</i> ₃	a_{1}	a_3	a_2	a_1	a_2	a_3	
	a_{l}	a_2	a_3	a_{l}	<i>a</i> ₃	a_2	a_{l}	a_2	a_3	
1	a_1		<i>a</i> ₃						a ₃ 4	2
	a_{l}	a_2	<i>a</i> ₃	a_{l}	a_3	a_2	a_{l}	a_2	a_3	
	a_1	<i>a</i> ₂	a_3	a_1		a_2	a_1	a_2	a_3	

$2a_1 + 2a_2 = 0$
$2a_2 + 2a_3 = 0$
$2a_1 + 2a_3 = 0$
$3a_2 + a_1 + a_3 = 0$
$3a_3 + a_1 + a_2 = 0$
$3a_1 + a_2 + a_3 = 0$

$$\bullet \ < a_1, a_2, a_3 | 2a_1 = 2a_2 = 2a_3 = a_1 + a_2 + a_3 = 0 >$$

$$15a_1 + 14a_2 + 15a_3 = a_1 + a_3$$



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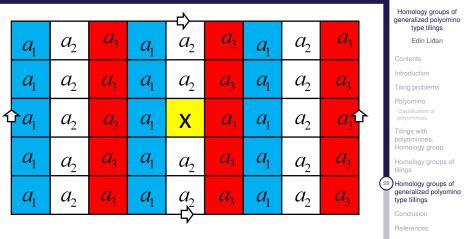


Figure: Coloring the chessboard

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The same idea can be used for studying tilings on surfaces of genus g. Which are subdivided in more general cells grids.





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Questions?

