m58775
Refinement of Trisoup projection plane determination for improving subjective quality

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Overview

■ Problem statement

- **In the previous meeting, some visual “holes” were found on reconstructed point cloud by TMC13-14.0 (fixed node size Trisoup).**
- **In this contribution, a cause of the problem is analyzed and solutions are proposed.**

■ Analysis and Proposed method

- **The cause of problem is found on the projection plane determination in the Trisoup decoding process.**
- **Two solutions are proposed.**
  - Method 1: Area of projected polygons
  - Method 2: Diagonal spread of vertices on projected planes

■ Experimental results

- **Objective quality: Both Method 1 and Method 2 have minor impact (D1/D2, -0.1%/-0.1%)**
- **Subjective quality: It is confirmed that “holes” disappeared.**

Problem Statement

- **In the previous meeting, some visual “holes” were found on reconstructed point cloud by TMC13-14.0 (fixed node size Trisoup).**

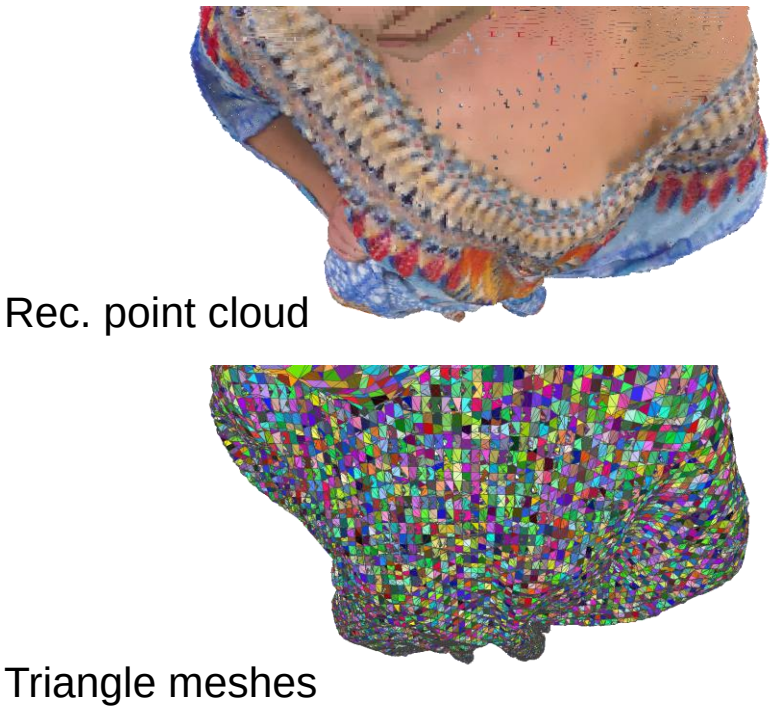
- **History**
  - **Further before, pointed out in Oct. 2020 meeting (m55493).**
  - **Partially solved in Jan. 2021 meeting (m55951).**

- **Goal of this contribution:**
  - **Analyze cause of the problem,**
  - **Propose solutions,**
  - **Confirm subjective quality improvement.**

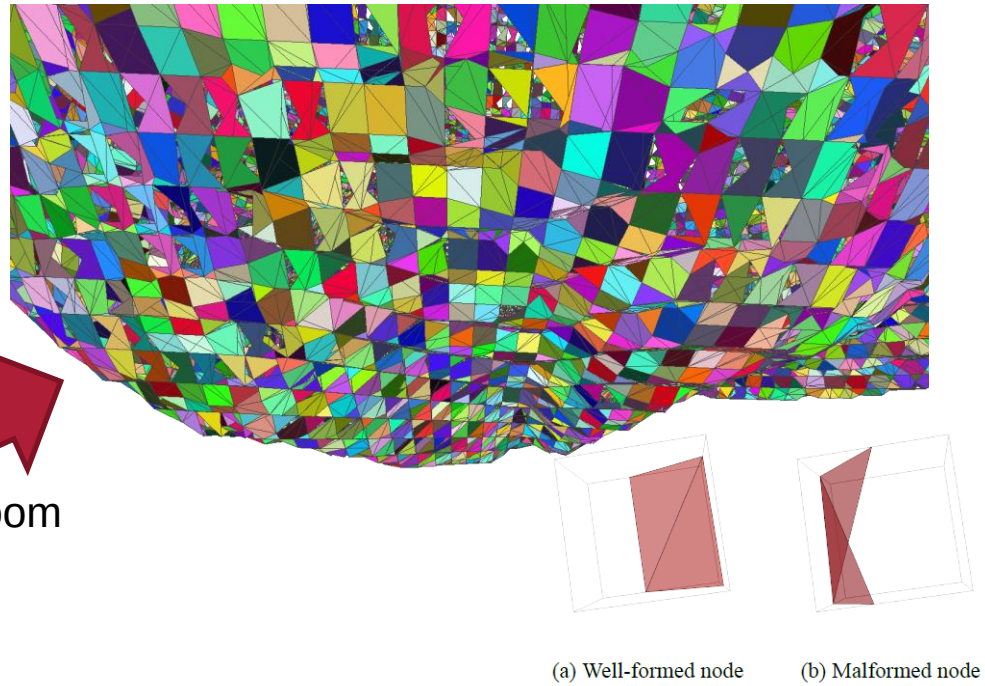
Rec. point cloud by TMC13-14.0
(r04, node size = 2^2)

Analysis

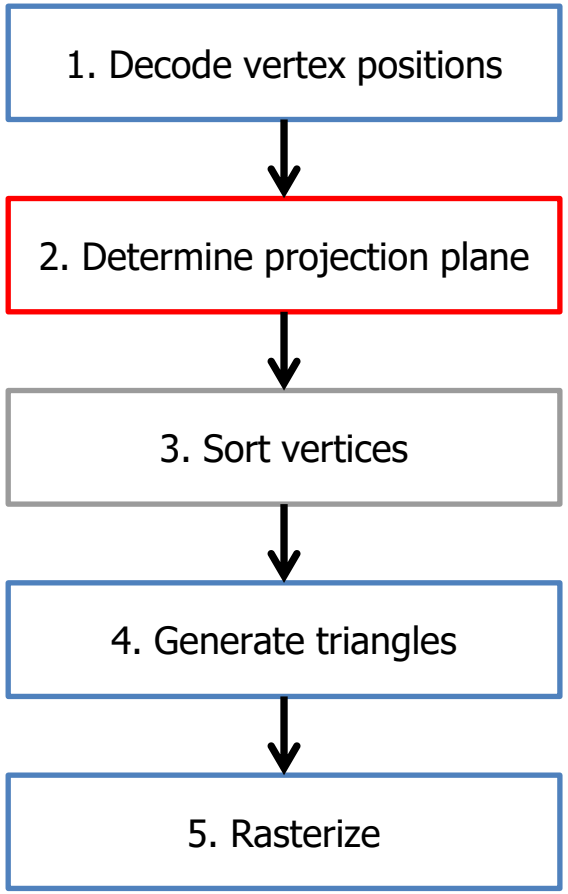
- **We tried to visualize triangle meshes (output of 4.).**
  - **Some malformed node still exist.**
  - **The cause of problem should be in 2. ~ 4.**
  - **A problem on 3. was solved in m55951.**
- **We checked 2. and found the problem on 2.**



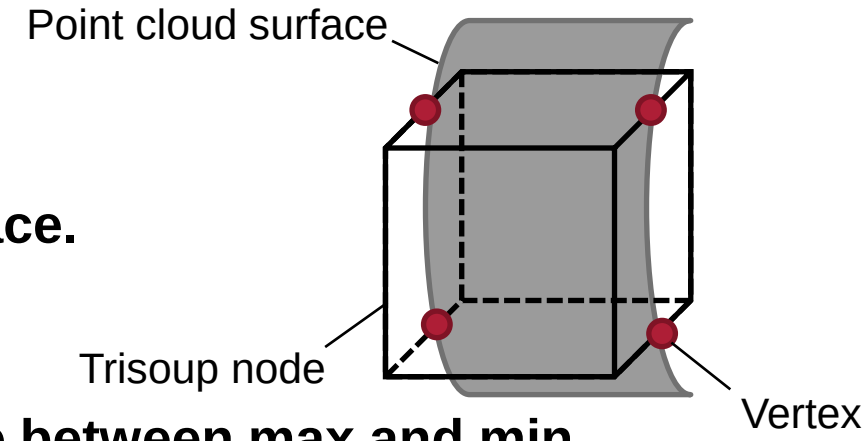
Zoom



Trisoup decoding process



Projection Plane Determination

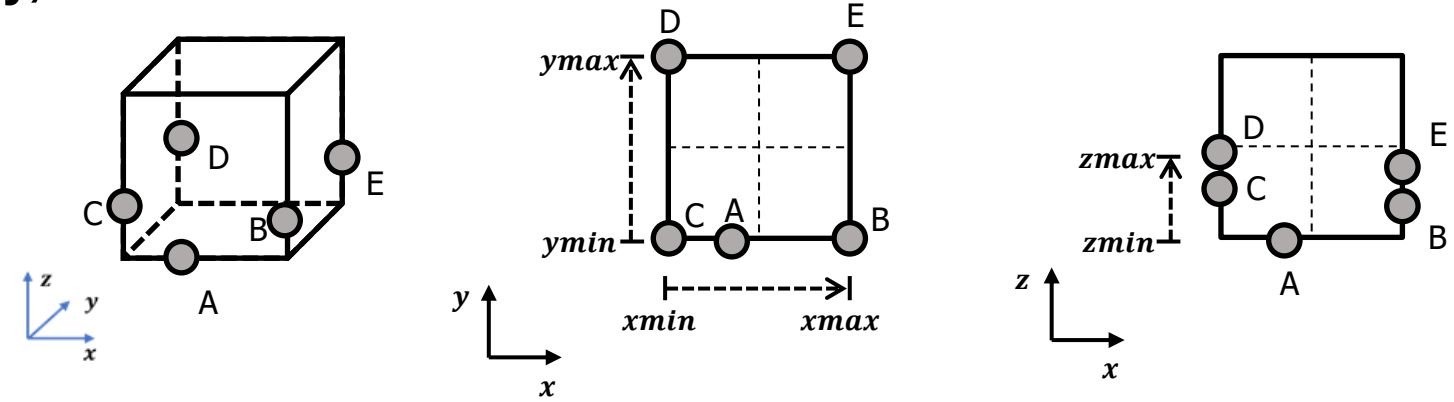


■ Design intention of Trisoup (our understanding)

- **Point cloud surface intersects a Trisoup node.**
- **Find the best projection plane approximates the surface.**

■ Current projection plane determination

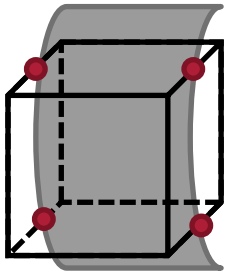
- **Shrink the axis with min. coordinate values difference between max and min.**
  - z axis is shrunk (i.e. x-y plane is used as projection plane) in the following example.
- **Previously, variances of coordinate values were used instead of differences.**



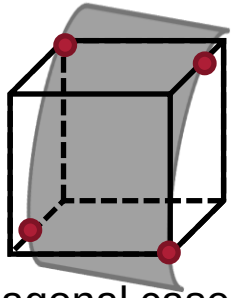
- **Cause of the problem: The current (and the previous) method(s) only evaluates 1-d spread of vertex positions.**

Problem on The Current Method

- The current method work well when a surface intersects a node orthogonally.
- However, it doesn't work when a surface intersects diagonally.

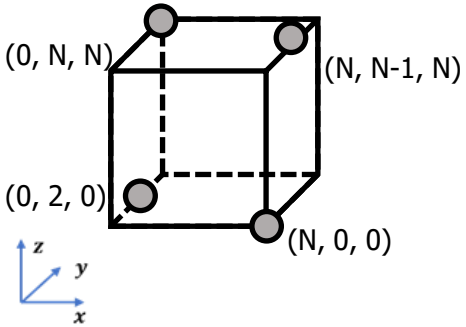


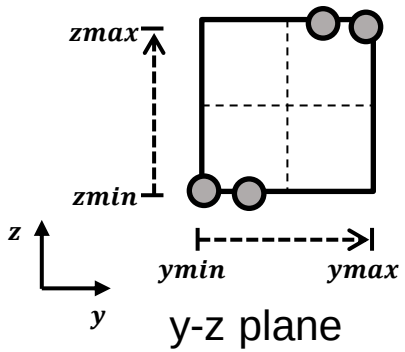
Orthogonal case



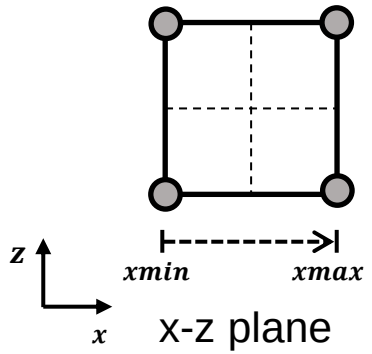
Diagonal case

- In diagonal case, differences for multiple axes have same value.
  - In that case, default axis (i.e. x axis) is shrunk. This may be cause of the miss-choice of the plane.
  - In the following example, x-z plane is the best but y-z plane is selected.

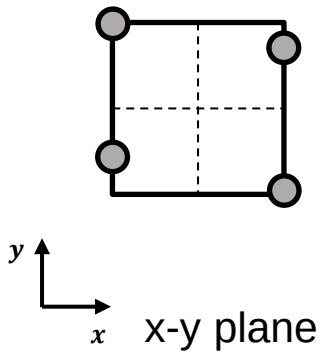




y-z plane



x-z plane



x-y plane

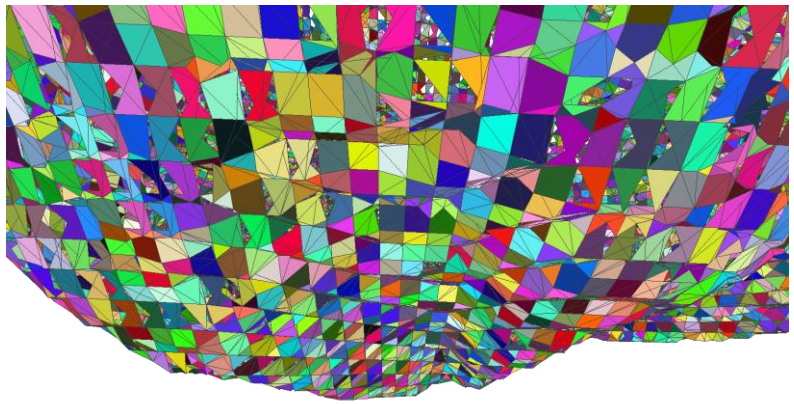
Verification of The Cause of Problem

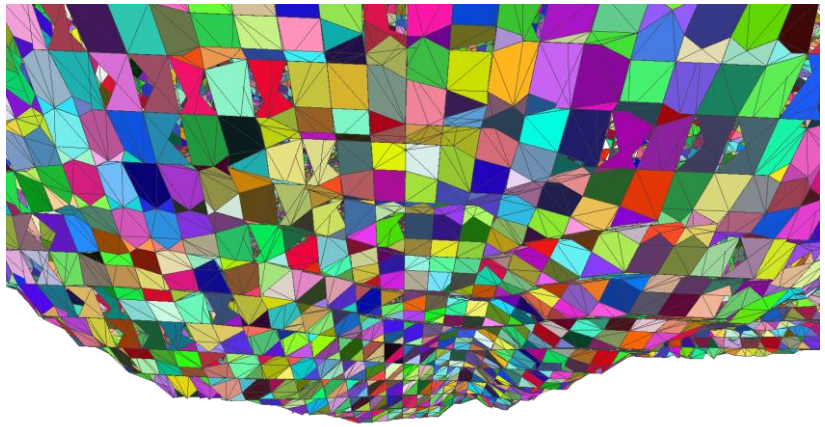
- **The problem also exist on previous method (variance).**
- **When default axis is change from x to z, problems on the example are disappeared.**

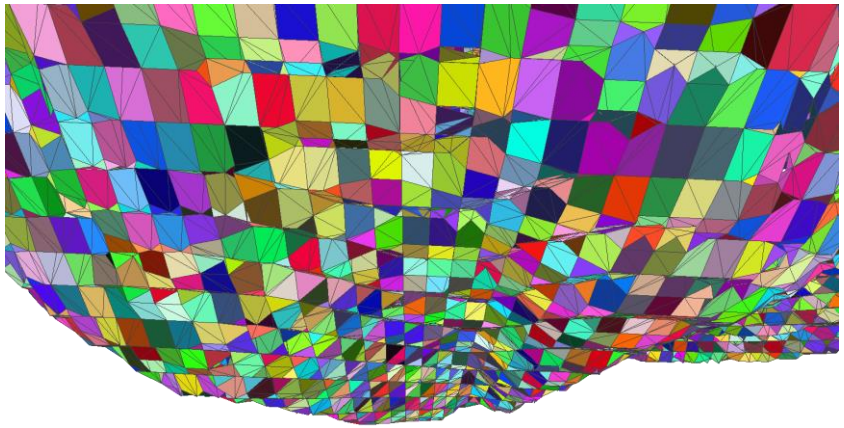
TMC13-v14.0 (default x)

Variance (default x)

TMC13-v14.0 (default z)





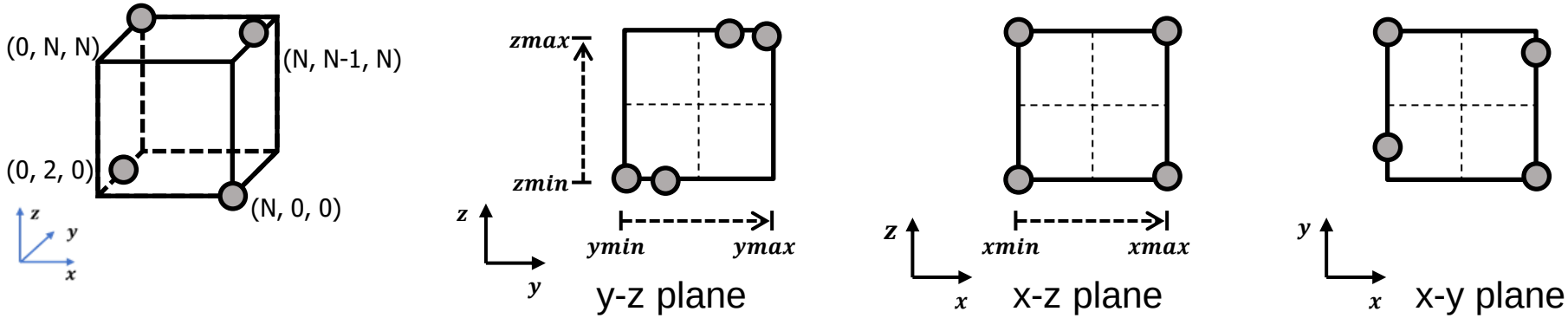


longdress_vox10_1300, r04

Proposed Solutions

How to select the best projection plane?

- **Basic idea: Evaluate 2-d spread of vertices instead of 1-d spread.**



Proposed Solutions

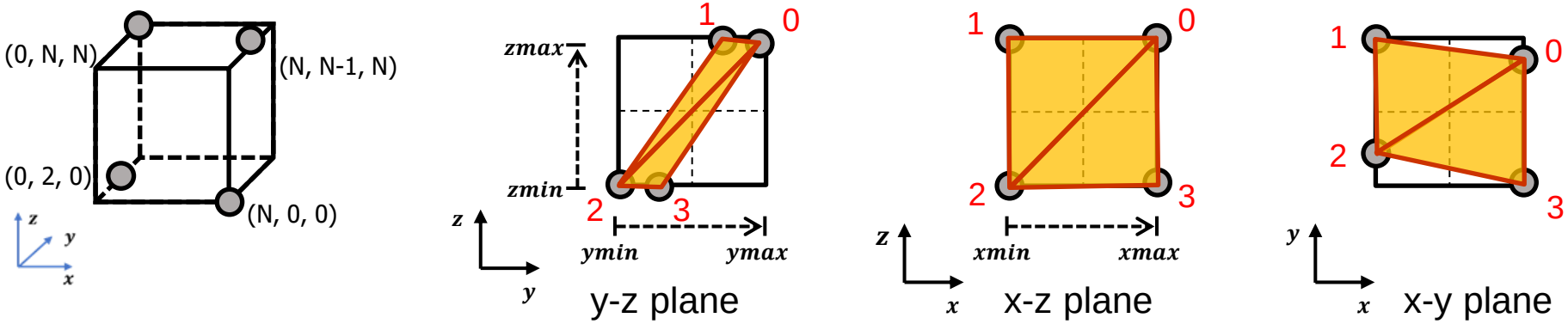
- **Method 1**
  - Select a projection plane with the max area of projected polygon.
- **Method 2**
  - Select a projection plane with the max diagonal spread of vertices on projected planes.

Method 1: Area of projected polygons

- **Select a projection plane with the max area of projected polygon.**
  1. **Sort vertices in anti-clockwise order for each plane (same as the current Trisoup decoding process).**
  2. **Make triangles with vertex (0, n-1, n) (n = 2,...,Number of vertices)**

     Triangles are defined as (0, 1, 2) and (0, 2, 3) in the following example.
  3. **Calculate area of each triangle by outer product.**
  4. **Select a projection plane with the max area of projected polygon.**

     x-z plane is selected in the following example.

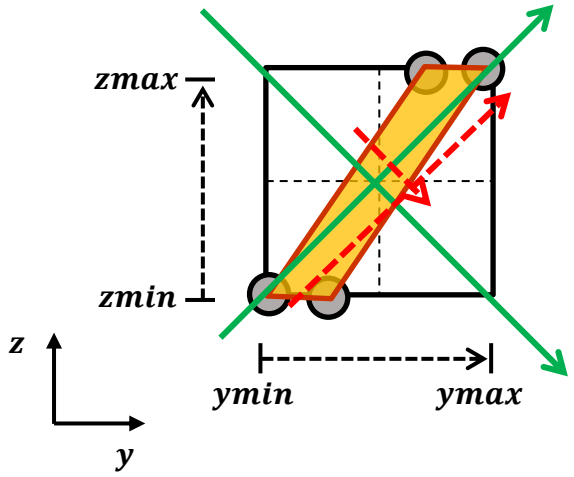


- **Pros: Theoretically one of the best solutions.**
- **Cons: Computational costs (needs some multiplies).**

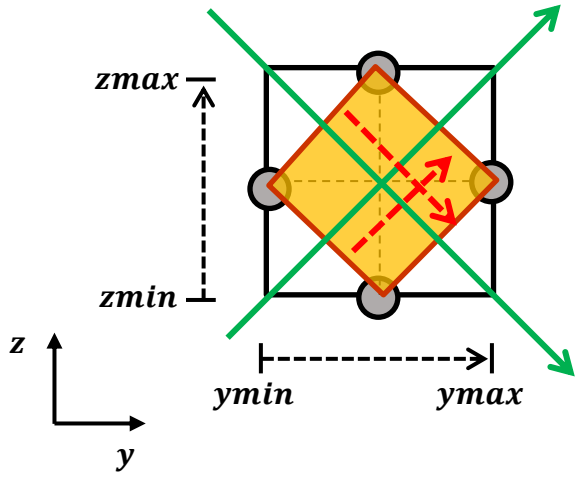
Method 2: Diagonal spread of vertices

- **How to find a plane with max area approximately?**
  - Diagonal spread of vertices may be more relative than orthogonal spread.

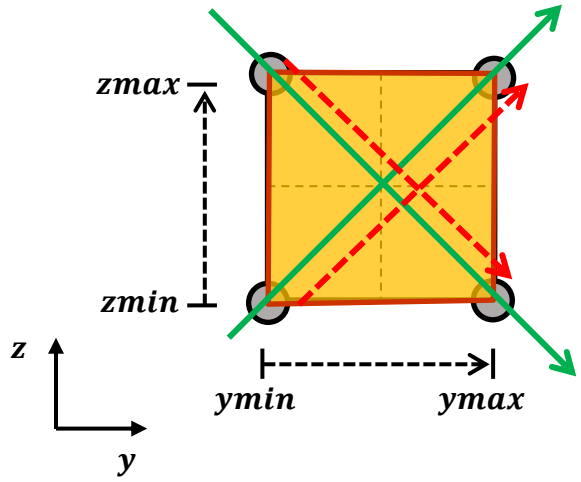
- **Example**
  - Area : (C) > (B) > (A). (C) is the max area case (vertices are on all corners).
  - Orthogonal spread (ymax – ymin, zmax – zmin) is same for (A), (B), and (C).
  - Diagonal spread (length of red arrows) can be approximates area.



(A)



(B)



(C)

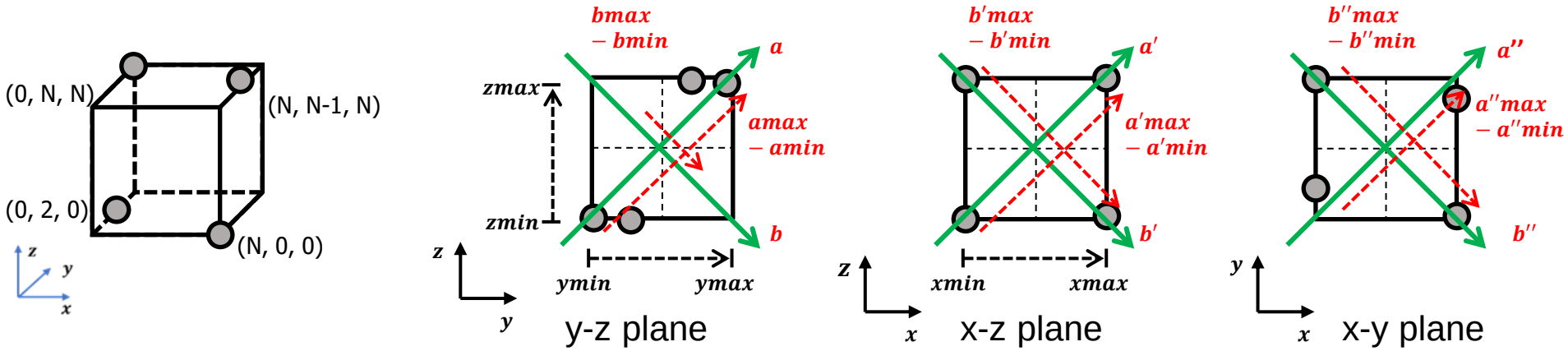
Method 2: Diagonal spread of vertices

- **Select a projection plane with the max diagonal spread of vertices on projected planes.**
  1. **Apply Hadamard transform for all vertices on each plane.**

     Here, normalization $(1/\sqrt{2})$ is not necessary.

$$\begin{pmatrix} a \\ b \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

  2. **Calculate difference between max value and min value on each transformed axis.**
  3. **Add differences on each plane (e.g. $D = (amax - amin) + (bmax - bmin)$)**
  4. **Select a plane which has the largest D.**



- **Pros: Relatively small computational costs (multiplication free).**
- **Cons: Method 1 is theoretically better.**

Worst Case Complexities for a node (with 12 vertices)

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Current implementation

- Step 1: Calculate diff. between max and min value.
- Step 2: Select plane.

	ADD	MUL	DIV	SHIFT	COMP
STEP 1	3	0	0	0	66
STEP 2	0	0	0	0	2
TOTAL	3	0	0	0	68

Method 1

- Step 1: Additional 2 sort processes.
- Step 2: Calculate area for each plane.
- Step 3: Select plane.

	ADD	MUL	DIV	SHIFT	COMP
STEP 1	24	24	0	0	138
STEP 2	123	60	0	0	0
STEP 3	0	0	0	0	2
TOTAL	147	84	0	0	140

Method 2

- Step 1: Apply Hadamard transform.
- Step 2: Calculate $D = (amax - amin) + (bmax - bmin)$.
- Step 3: Select plane.

	ADD	MUL	DIV	SHIFT	COMP
STEP 1	72	0	0	0	0
STEP 2	9	0	0	0	132
STEP 3	0	0	0	0	2
TOTAL	81	0	0	0	134

Experimental results

Conditions

- Anchor : TMC13-v14.0
- Test : TMC13-v14.0 + Proposed method
- Trisoup – RAHT (Only C2 condition, Cat1 Sequences)

Objective quality

- Minor impacts for objective qualities.
- Over all processing times are almost same as the anchor.

TMC13-v14.0 vs. Method 1

C2_ai	lossy geometry, lossy attributes [all intra] Geom. BD-TotGeomRate [%] D1	D2
Solid average	0.1%	−0.1%
Dense average	0.0%	0.0%
Sparse average	−0.3%	−0.5%
Scant average	−0.1%	0.1%
Overall average	−0.1%	−0.1%
Avg. Enc Time [%]	99%	
Avg. Dec Time [%]	100%	

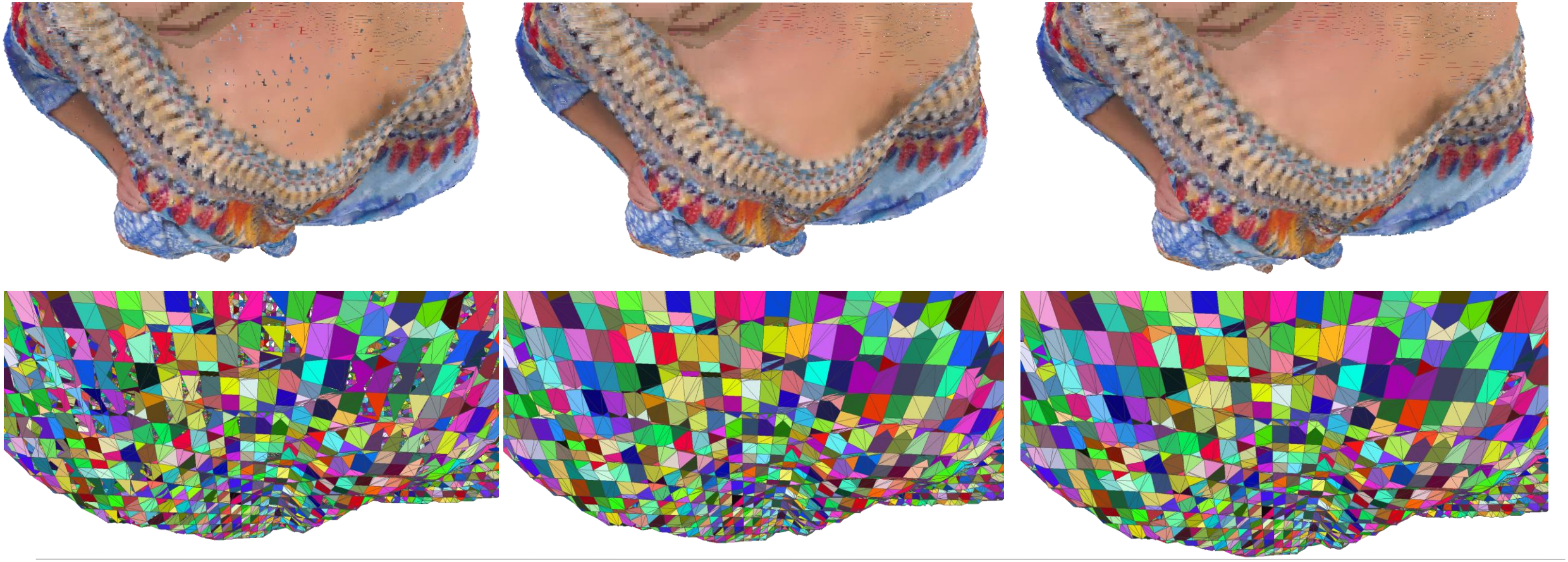
TMC13-v14.0 vs. Method 2

C2_ai	lossy geometry, lossy attributes [all intra] Geom. BD-TotGeomRate [%] D1	D2
Solid average	0.1%	0.0%
Dense average	0.0%	0.0%
Sparse average	−0.4%	−0.5%
Scant average	−0.2%	0.1%
Overall average	−0.1%	−0.1%
Avg. Enc Time [%]	100%	
Avg. Dec Time [%]	100%	

Subjective Quality

- **Method 1: probably all problems are solved.**
- **Method 2: only a few holes still exist.**

TMC13-v14.0 | Method 1 | Method 2



longdress_vox10_1300, r04

Subjective Quality

■ **queen_0200, r04 and loot_vox10_1200, r04**

TMC13-v14.0

Method 1

Method 2

Conclusion

- **Problem statement**
  - **In the previous meeting, some visual “holes” were found on reconstructed point cloud by TMC13-14.0 (fixed node size Trisoup).**
  - **In this contribution, a cause of the problem is analyzed and solutions are proposed.**
- **Analysis and Proposed method**
  - **The cause of problem is found on the projection plane determination in the Trisoup decoding process.**
  - **Two solutions are proposed.**
    - Method 1: Area of projected polygons
    - Method 2: Diagonal spread of vertices on projected planes
- **Experimental results**
  - **Objective quality: Both Method 1 and Method 2 have minor impact (D1/D2, -0.1%/-0.1%)**
  - **Subjective quality: It is confirmed that “holes” disappeared.**
- **Recommendation**
  - **Adopt Method 1 or Method 2 to the next version of TMC13.**
  - **If there is no concern on computational cost, Method 1 is recomennded.**

Thank Sony for cross-checking.