May/20/2015

Programming Assignment:

Mesh Unfolding Heuristics

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1.   Objective

My goal is to provide an implementation of a couple of unfolding heuristics from 'Schlickenrieder, Wolfram. "Nets of polyhedra." Master's Thesis, Technische Universität Berlin (1997).'

2.   Methods

I chose two methods, which are "Greatest increase unfold" and "Rightmost ascending edge unfold" and I implemented them.

3.   Results

I test my two method, which are "Greatest increase unfold" and "Rightmost ascending edge unfold" and also test "Steepest edge cut tree" and "Flat edge unfolding". I will show the results of all four methods with five convex models and five non-convex models in "Release" mode.
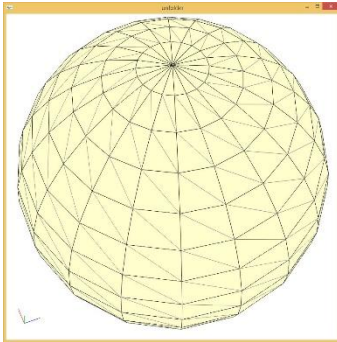
A. Five convex models

: I test the models; ball.obj, cone.obj, cube.obj, ellip.obj, pyramid2.obj in the "models/convex-models" folder

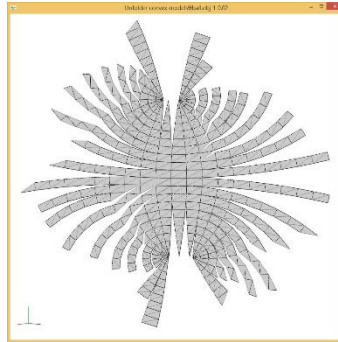**(1) ball.obj:** 382 vertices, 1140 edges, and 760 faces

(a) ~ (d) result info.

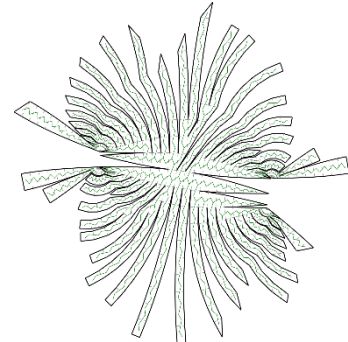|	(a)	(b)	(c)	(d)
Flattened	Yes	Yes	Yes	Yes
Total time	12.074 sec	18.715 sec	14.933 sec	12.962 sec
Average path length	18.2316	33.5776	18.9526	29.3605

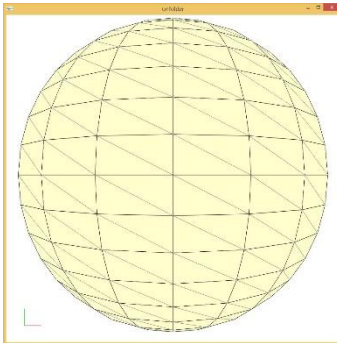**(a) Steepest edge cut tree**

(a-1) The ball model

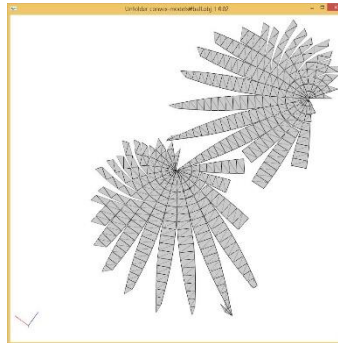(a-2) The unfolded ball model

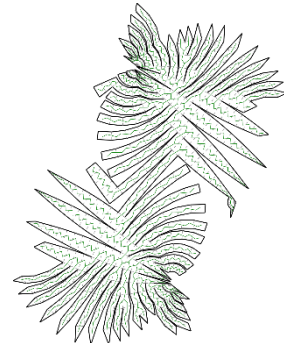(a-3) The tree graph of the ball model

(b) Flat edge unfolding
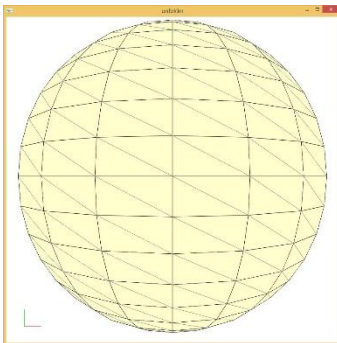

(b-1) The ball model

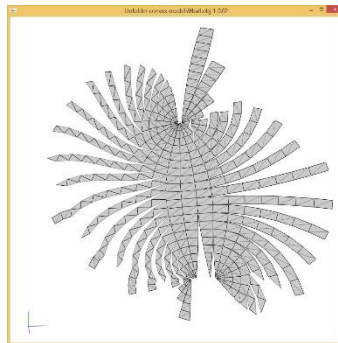(b-2) The unfolded ball model

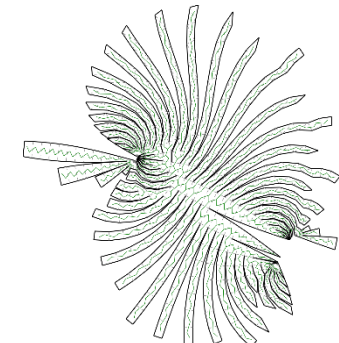
(b-3) The tree graph of the ball model

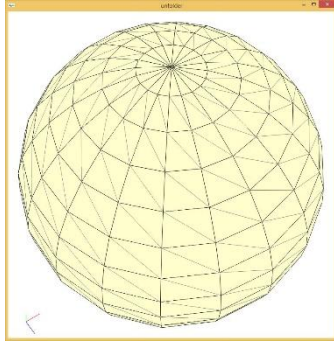**(c) Greatest increase unfold**

(c-1) The ball model

(c-2) The unfolded ball model

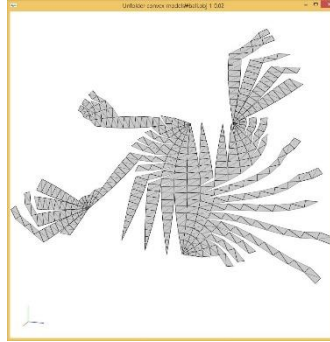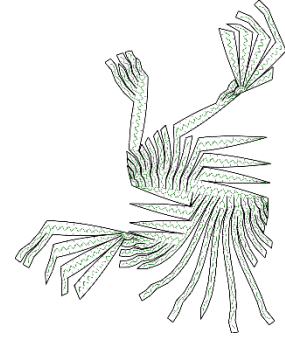(c-3) The tree graph of the ball model

(d) Rightmost ascending edge unfold
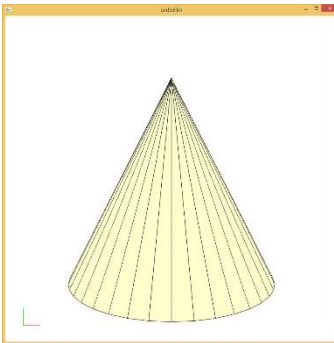

(d-1) The ball model

(d-2) The unfolded ball model

(d-3) The tree graph of the ball model
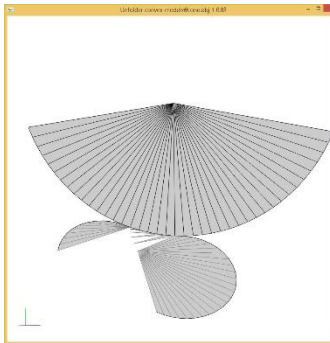
(2) cone.obj: 41 vertices, 117 edges, and 78 faces

(a) ~ (d) result info.

	(a)	(b)	(c)	(d)
Flattened	Yes	Yes	Yes	Yes
Total time	1.122 sec	1.1 sec	1.107 sec	1.213 sec
Average path length	10.6282	10.9103	10.3846	11.2821

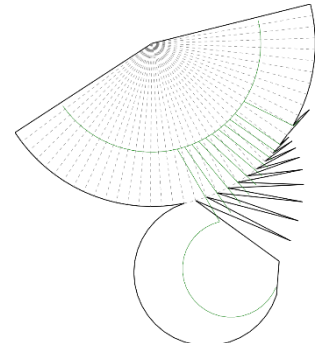### (a) Steepest edge cut tree

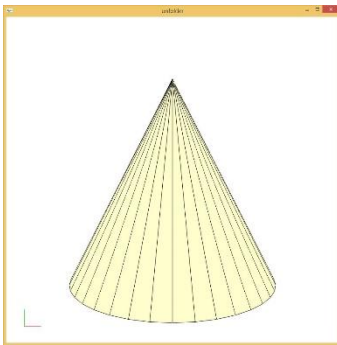
(a-1) The cone model

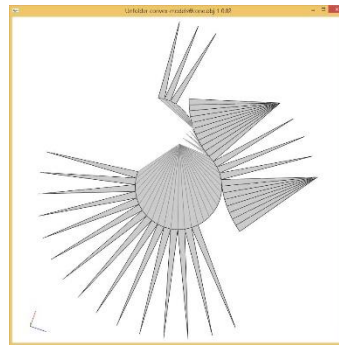(a-2) The unfolded cone model
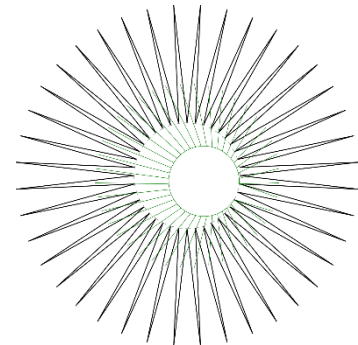

(a-3) The tree graph of the cone model

(b) Flat edge unfolding
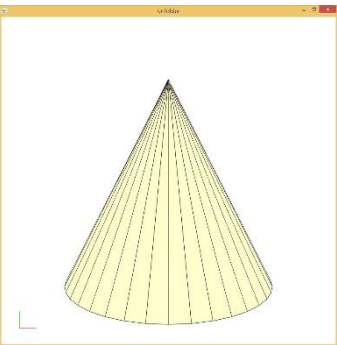

(b-1) The cone model
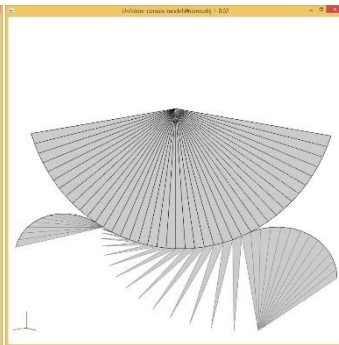

(b-2) The unfolded cone model
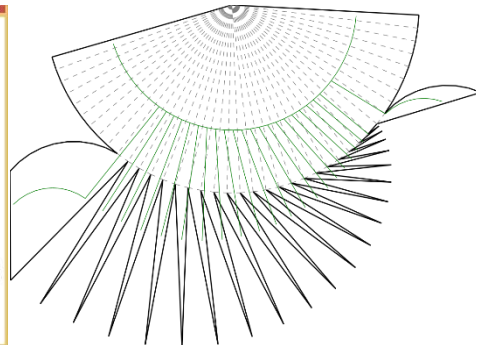

(b-3) The tree graph of the cone model

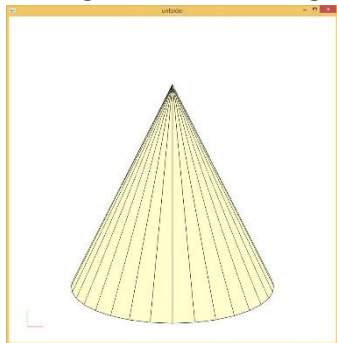**(c) Greatest increase unfold**

(c-1) The cone model

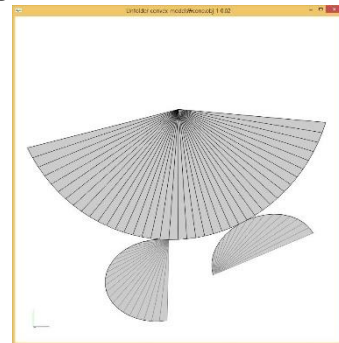(c-2) The unfolded cone model
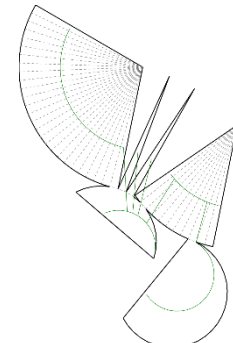

(c-3) The tree graph of the cone model

(d) Rightmost ascending edge unfold

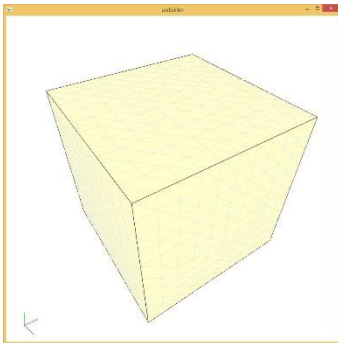

(d-1) The cone model

(d-2) The unfolded cone model

(d-3) The tree graph of the cone model
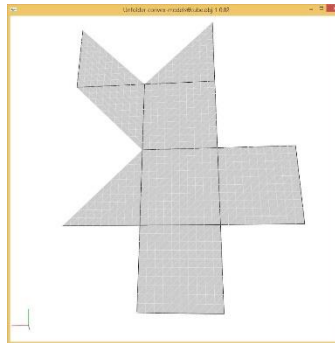
(3) cube.obj: 602 vertices, 1800 edges, and 1200 faces

    (a) ~ (d) result info.

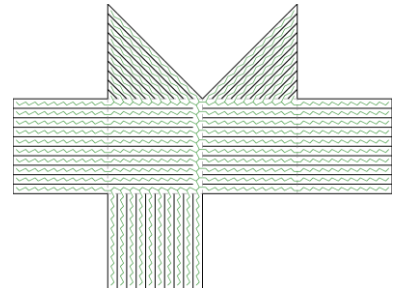|	(a)	(b)	(c)	(d)
Flattened	Yes	Yes	Yes	Yes
Total time	33.862 sec	69.028 sec	36.256 sec	30.308 sec
Average path length	24.6833	147.485	21.8917	32.17

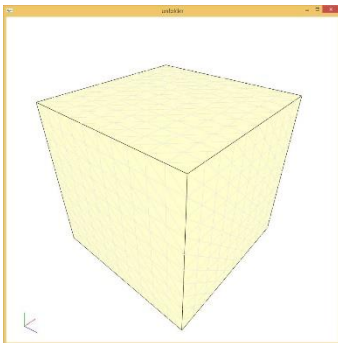**(a) Steepest edge cut tree**

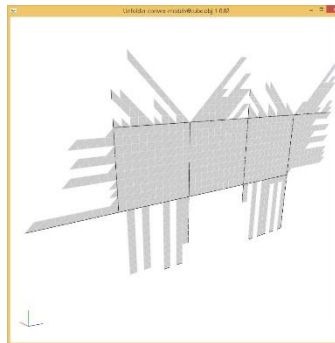(a-1) The cube model

(a-2) The unfolded cube model

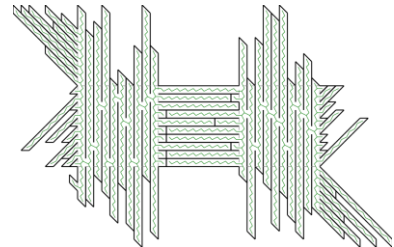(a-3) The tree graph of the cube model

(b) Flat edge unfolding
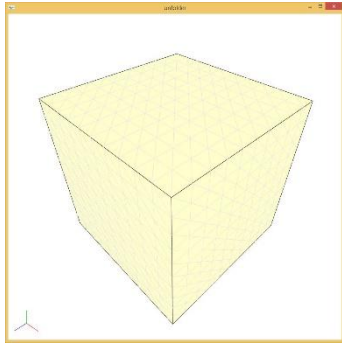

(b-1) The cube model

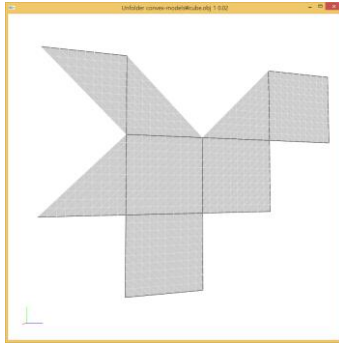(b-2) The unfolded cube model

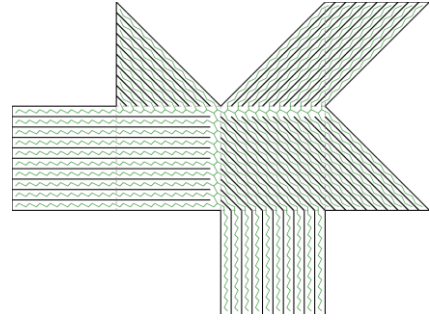(b-3) The tree graph of the cube model

(c) Greatest increase unfold
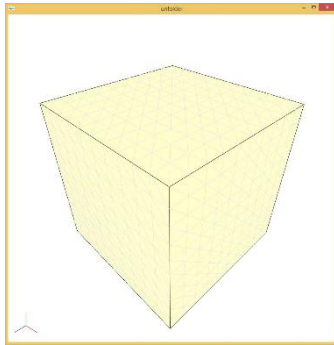

(c-1) The cube model
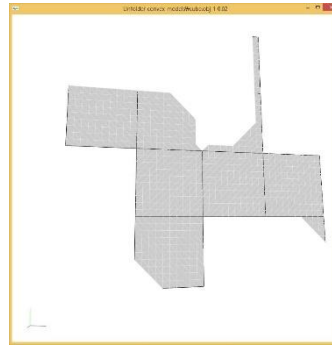

(c-2) The unfolded cube model

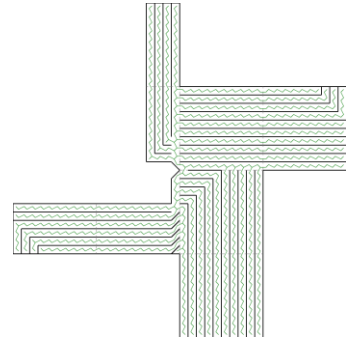(c-3) The tree graph of the cube model

(d) Rightmost ascending edge unfold

(d-1) The cube model

(d-2) The unfolded cube model

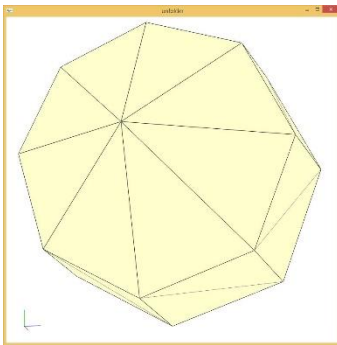

(d-3) The tree graph of the cube model

(4) **ellip.obj:** 26 vertices, 72 edges, and 48 faces

(a) ~ (d) result info.

	(a)	(b)	(c)	(d)
Flattened	Yes	Yes	Yes	Yes
Total time	0.747 sec	0.812 sec	0.828 sec	0.553 sec
Average path length	4.29167	6.125	4.375	7.20833

(a) Steepest edge cut tree

(a-1) The ellip model
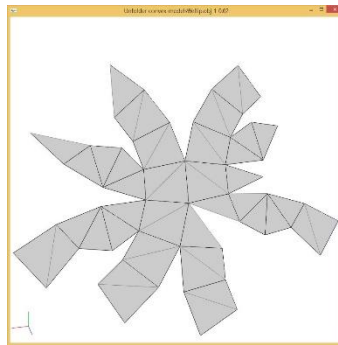
(a-2) The unfolded ellip model
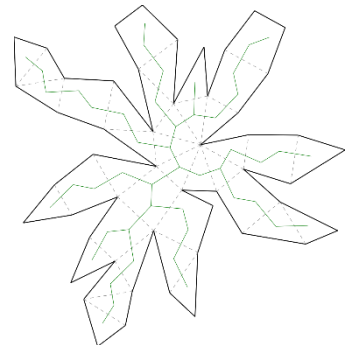
(a-3) The tree graph of the ellip model

(b) Flat edge unfolding

(b-1) The ellip model

(b-2) The unfolded ellip model

(b-3) The tree graph of the ellip model

(c) Greatest increase unfold

(c-1) The ellip model

(c-2) The unfolded ellip model

(c-3) The tree graph of the ellip model

(d) Rightmost ascending edge unfold

(d-1) The ellip model

(d-2) The unfolded ellip model
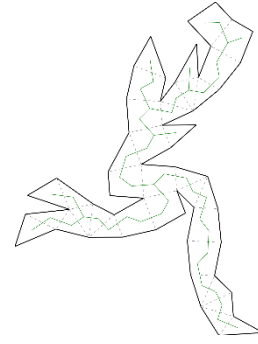
(d-3) The tree graph of the ellip model

(5) v-rod.obj: 164 vertices, 486 edges, and 324 faces
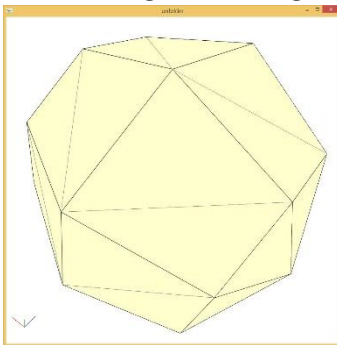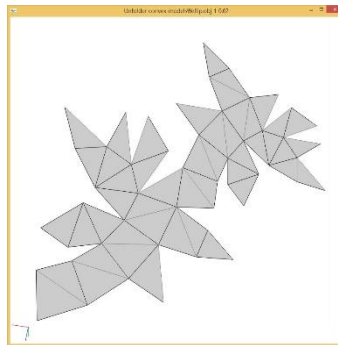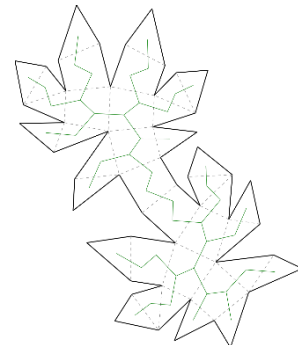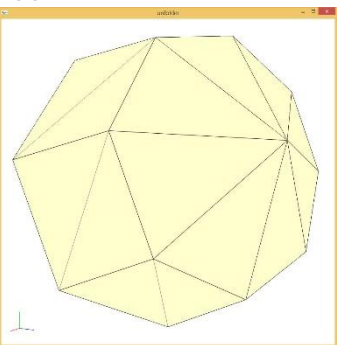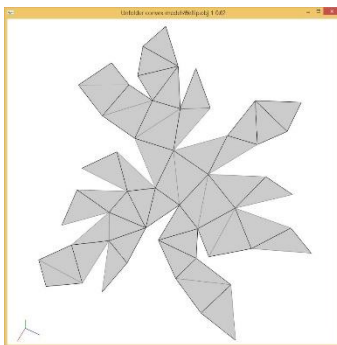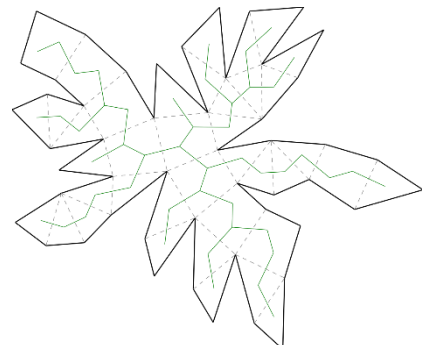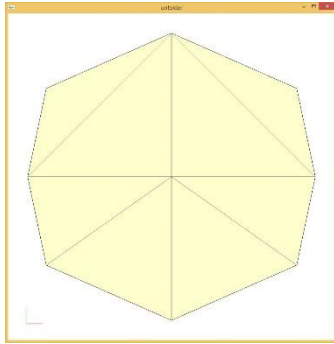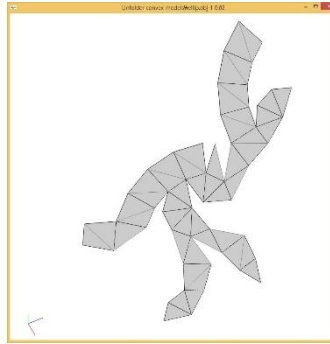
(a) ~ (d) result info.

	(a)	(b)	(c)	(d)
Flattened	Yes	Yes	Yes	Yes
Total time	5.122 sec	4.332 sec	4.955 sec	4.048 sec
Average path length	21.8611	22.2315	21.8704	27.3148

(a) Steepest edge cut tree

(a-1) The v-rod model
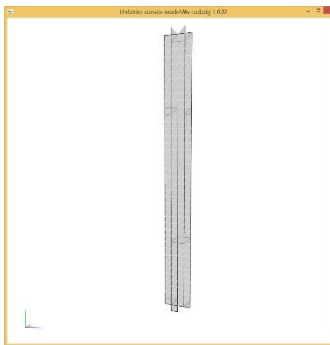
(a-2) The unfolded v-rod model

(a-3) The tree graph of the v-rod model

(b) Flat edge unfolding

(b-1) The v-rod model

(b-2) The unfolded v-rod model

(b-3) The tree graph of the v-rod model

(c) Greatest increase unfold

(c-1) The v-rod model

(c-2) The unfolded v-rod model

(c-3) The tree graph of the v-rod model

(d) Rightmost ascending edge unfold

(d-1) The v-rod model
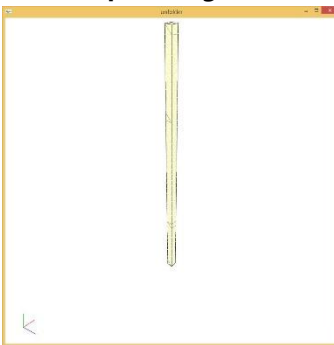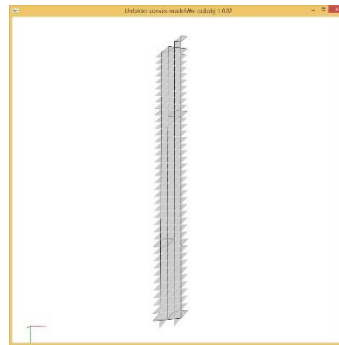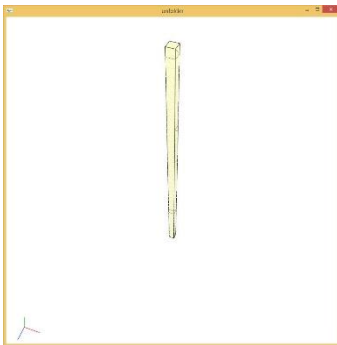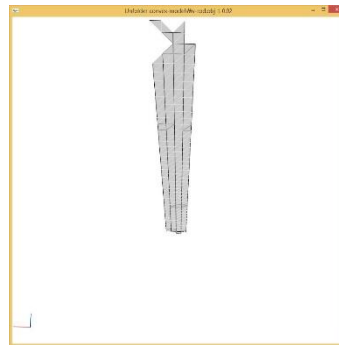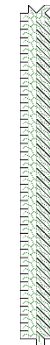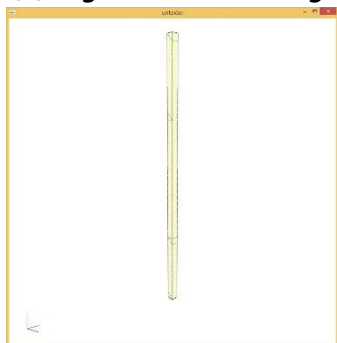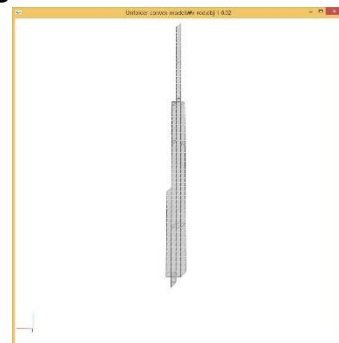

(d-2) The unfolded v-rod model

(d-3) The tree graph of the v-rod model
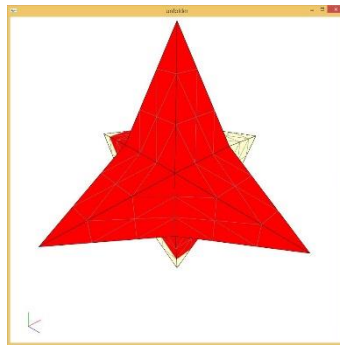
B. Five non-convex models

: I test the models; star-9split.obj, bunny-348.obj, kitten-122.obj, hand-336.obj, tower-412.obj in the "models" folder

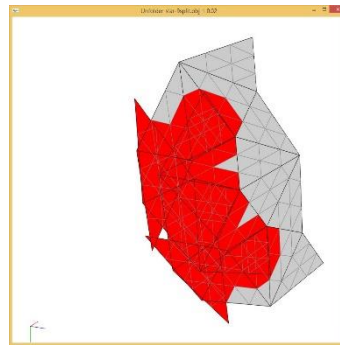**(1) star-9split.obj:** 110 vertices, 324 edges, and 216 faces

(a) ~ (d) result info.

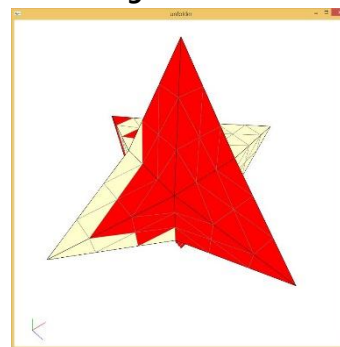|	(a)	(b)	(c)	(d)
Flattened	No	No	No	No
Total time	10.122 sec	9.524 sec	10.318 sec	7.632 sec
Average path length	-	-	-	-

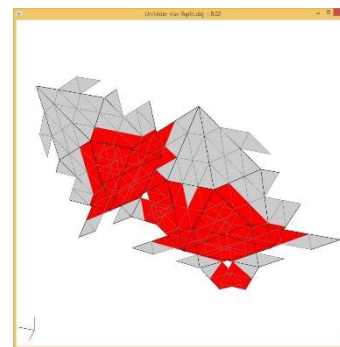**(a) Steepest edge cut tree**

(a-1) The star-9split model

(a-2) The unfolded star-9split model

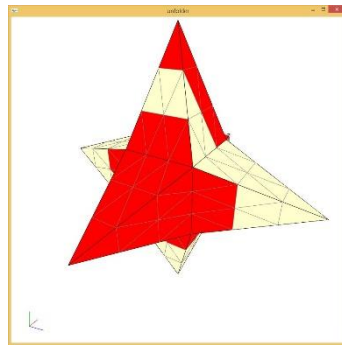**(b) Flat edge unfolding**

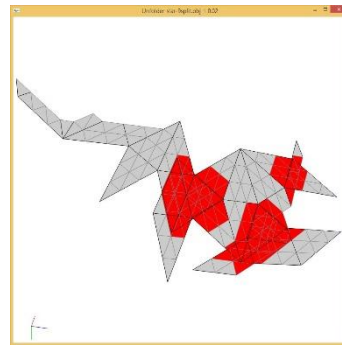(b-1) The star-9split model

(b-2) The unfolded star-9split model
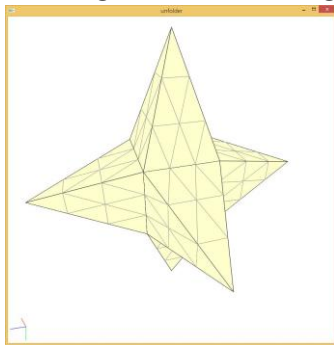
(c) Greatest increase unfold

(c-1) The star-9split model

(c-2) The unfolded star-9split model

(d) Rightmost ascending edge unfold

(d-1) The star-9split model
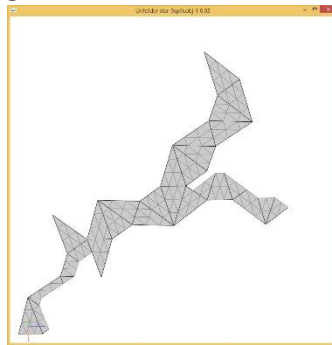
(d-2) The unfolded star-9split model
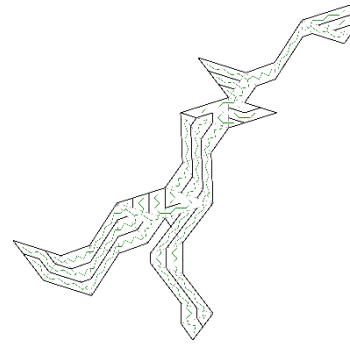
(d-3) The tree graph of the star-9split model

(2) bunny-348.obj: 176 vertices, 522 edges, and 348 faces

(a) ~ (d) result info.

	(a)	(b)	(c)	(d)
Flattened	No	No	No	No
Total time	9.21 sec	12.221 sec	12.674 sec	16.454 sec
Average path length	-	-	-	-

(a) Steepest edge cut tree

(a-1) The bunny-348 model
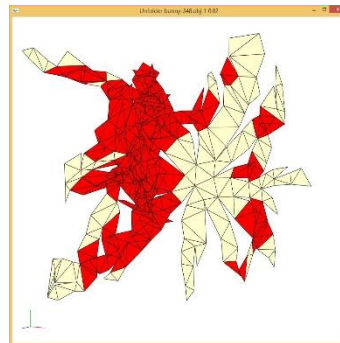
(a-2) The unfolded bunny-348 model

(b) Flat edge unfolding

(b-1) The bunny-348 model

(b-2) The unfolded bunny-348 model

(c) Greatest increase unfold

(c-1) The bunny-348 model
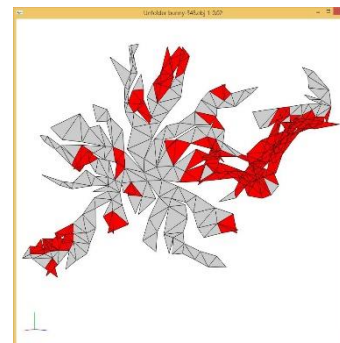
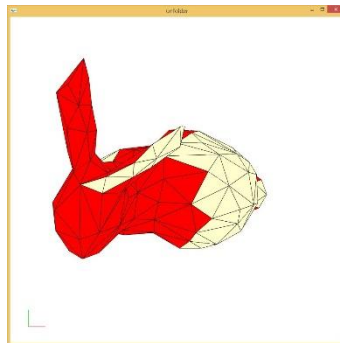(c-2) The unfolded bunny-348 model

(d) Rightmost ascending edge unfold
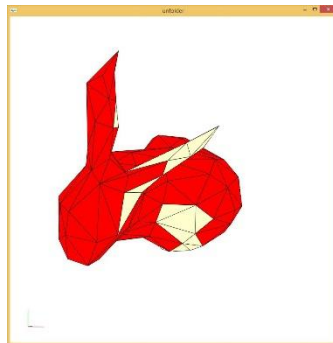
(d-1) The bunny-348 model

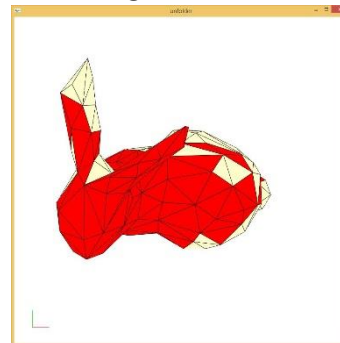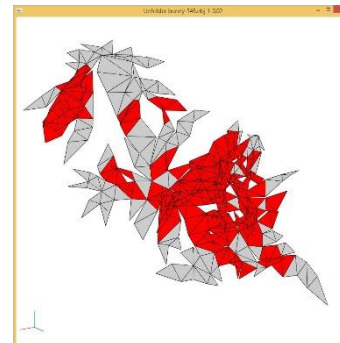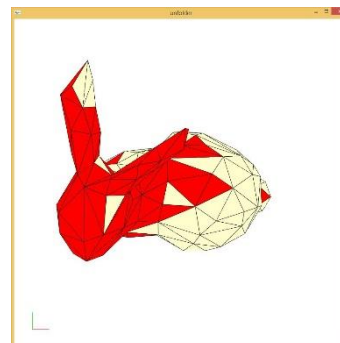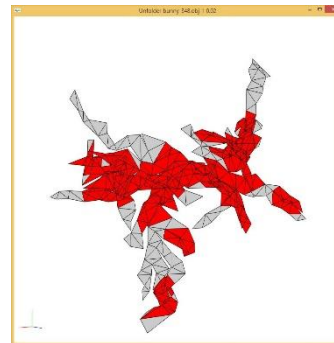(d-2) The unfolded bunny-348 model

(3) kitten-122.off: 64 vertices, 183 edges, and 122 faces

    (a) ~ (d) result info.

	(a)	(b)	(c)	(d)
Flattened	No	No	No	No
Total time	10.264 sec	9.606 sec	11.426 sec	8.785 sec
Average path length	-	-	-	-

(a) Steepest edge cut tree
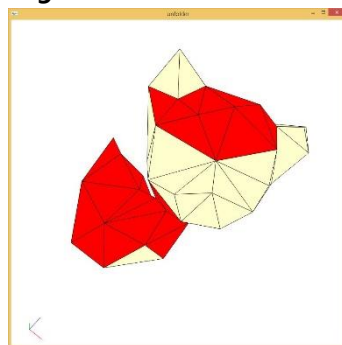
(a-1) The kitten-122 model
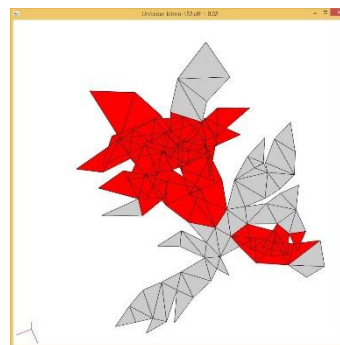
(a-2) The unfolded kitten-122 model

(b) Flat edge unfolding
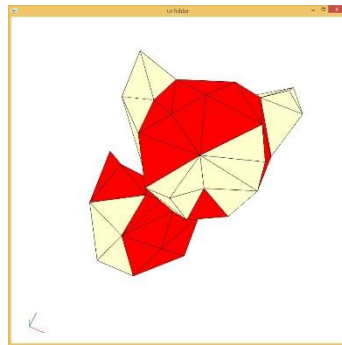
(b-1) The kitten-122 model
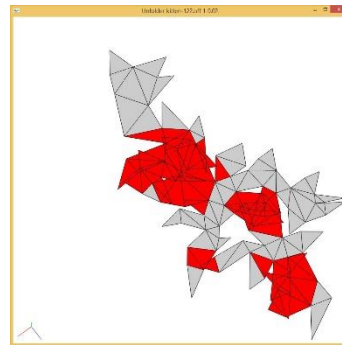
(b-2) The unfolded kitten-122 model

(c) Greatest increase unfold
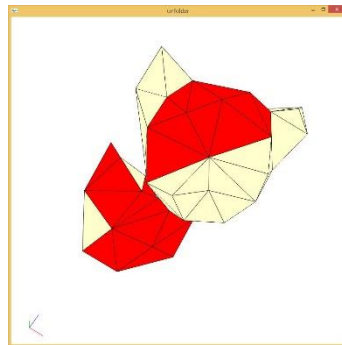
(c-1) The kitten-122 model
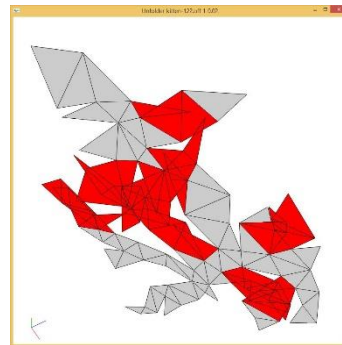
(c-2) The unfolded kitten-122 model

(d) Rightmost ascending edge unfold
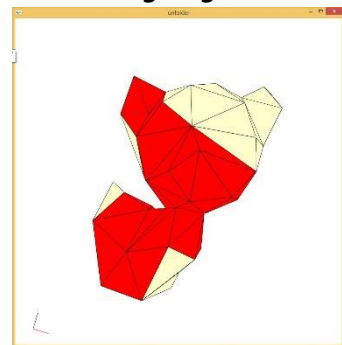
(d-1) The kitten-122 model
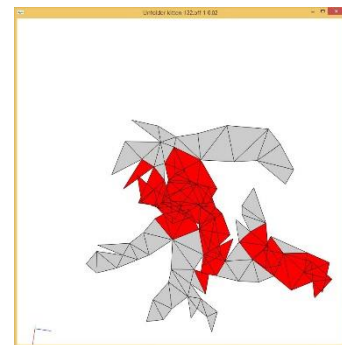
(d-2) The unfolded kitten-122 model

(4) hand-336.off: 170 vertices, 504 edges, and 336 faces

(a) ~ (d) result info.

	(a)	(b)	(c)	(d)
Flattened	No	No	No	No
Total time	12.068 sec	7.787 sec	14.328 sec	12.098 sec
Average path length	-	-	-	-

(a) Steepest edge cut tree
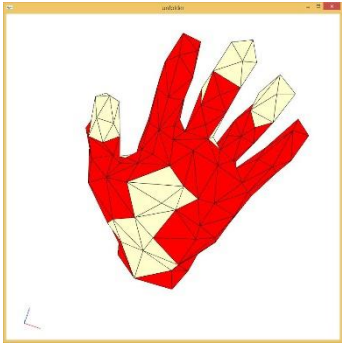
(a-1) The hand-336 model
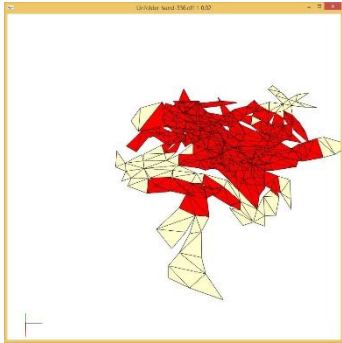
(a-2) The unfolded hand-336 model

(b) Flat edge unfolding

(b-1) The hand-336 model
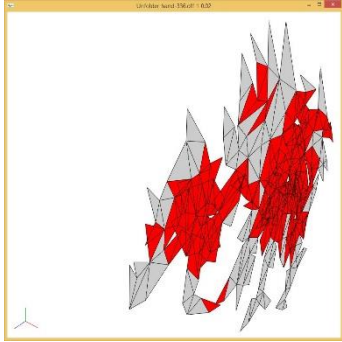
(b-2) The unfolded hand-336 model

(c) Greatest increase unfold
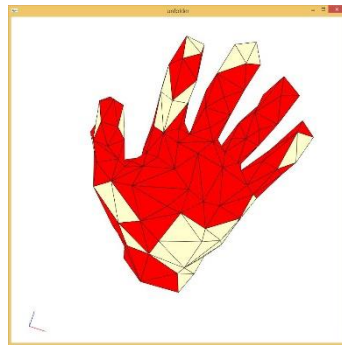
(c-1) The hand-336 model
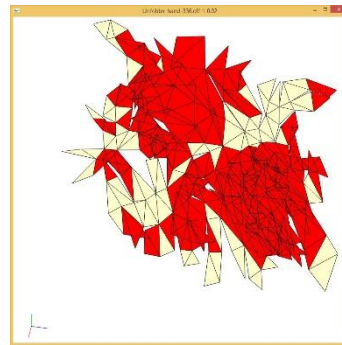
(c-2) The unfolded hand-336 model

(d) Rightmost ascending edge unfold
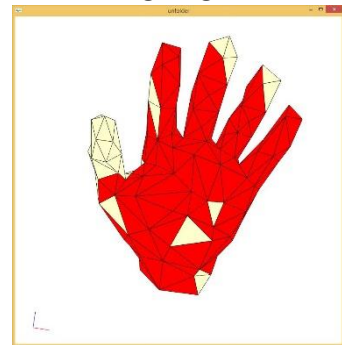
(d-1) The hand-336 model
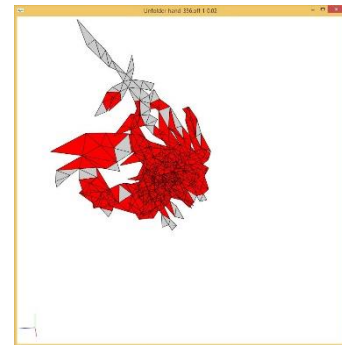
(d-2) The unfolded hand-336 model

**(5) <u>tower-412.obj:</u>** 208 vertices, 618 edges, and 412 faces

(a) ~ (d) result info.

	(a)	(b)	(c)	(d)
Flattened	No	No	No	No
Total time	14.723 sec	11.408 sec	13.164 sec	9.46 sec
Average path length	-	-	-	-

(a) Steepest edge cut tree
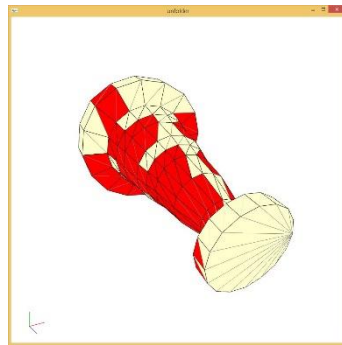
(a-1) The tower-412 model
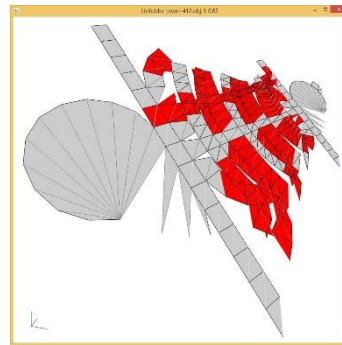
(a-2) The unfolded tower-412 model

(b) Flat edge unfolding

(b-1) The tower-412 model

(b-2) The unfolded tower-412 model

**(c) Greatest increase unfold**

(c-1) The tower-412 model

(c-2) The unfolded tower-412 model

(d) Rightmost ascending edge unfold

(d-1) The tower-412 model

(d-2) The unfolded tower-412 model

4. Foundings

I used four methods to unfold meshes. The four methods are the Steepest edge cut tree, the Flat edge unfolding, the Greatest increase unfold, and the Rightmost ascending edge unfold.
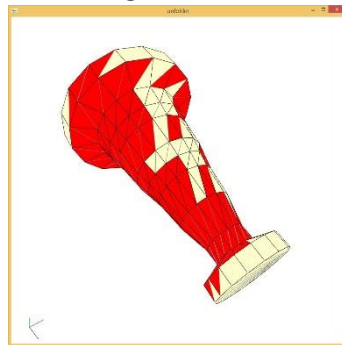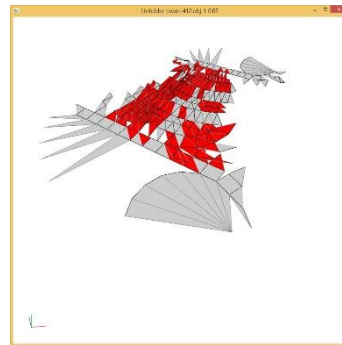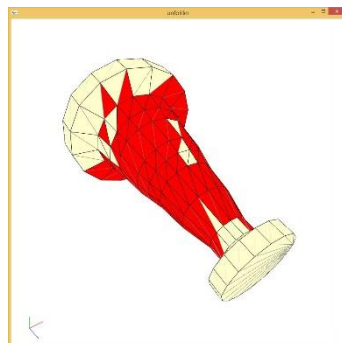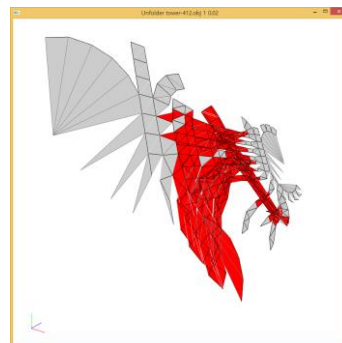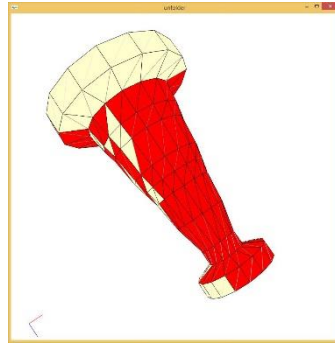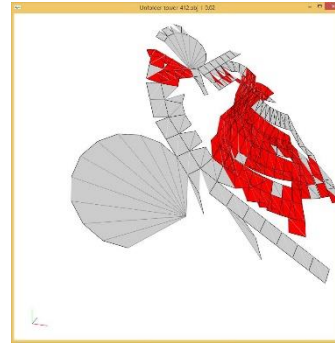
The Steepest edge cut tree is to cut along paths that are as straight as possible. I picked a top vertex and a bottom vertex along the random vector. For all vertices except the top vertex, find the steepest edges using inner product.

The Greatest increase unfold is very similar to the Steepest edge cut tree but it considers the edge length and the edge direction which is positive. Conceptually, the greatest increase unfold is very similar to the Steepest edge cut tree method.

Unlike the Steepest edge cut tree, the Flat edge unfolding is to join facets along flat edges which are as perpendicular as possible to a random vector.

The Rightmost ascending edge unfold is to compute the rightmost ascending edge using inner product and determinant.

Most of all method cut edges of convex model well without overlapping but they didn't cut edges of non-convex model without overlapping. I think this is because we set only one start vertex and only one goal vertex. So, I cannot cut edges of non-convex model without overlapping. The non-convex mesh has many curves which cannot be solved using one start and one goal vertex. To unfold non-convex shapes, we need other start or goal vertex. For example, we make clusters which have a start vertex respectively and unfold each cluster. Then we can get the unfolded meshes without overlapping themselves