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Missing Point on the Corner by using Extension Cases of Advancing Front Mesh Method

Noorehan Awang[1,2], Rahmita Wirza Rahmat[1], Ng Seng Beng[1], Azmi Jaafar[1], Puteri Suhaiza Sulaiman[1], Mohd Rijal Ilias[3]
[1]Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia, gs43550@student.upm.edu.my, rahmita@fsktm.upm.edu.my, ngsengbeng@upm.edu.my, azmij@upm.edu.my, psuhaiza@upm.edu.my
[2]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA (UiTM),70300 Seremban, Negeri Sembilan, Malaysia, noorehan@uitm.edu.my
[3]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA (UiTM),40450 Shah Alam, Selangor, Malaysia,mrijal@uitm.edu.my

ABSTRACT

Surface reconstruction was mainly the important process in reverse engineering. However undesirable holes often exist due to accessibility limitation on scanners. To bridge the gap, the paper proposes an enhanced algorithm of filling holes for 3D objects based on Advancing Front Mesh (AFM) method. The holes focused was on the missing point on the corner of the object. In the algorithm, object was chosen and two procedure used to achieved the results. The procedure consists of two steps namely hole detection and hole filling. The experiment demonstrates the result of hole filling can recover the original shape of the hole region precisely and effectively.

Key words : Advancing front mesh, delaunay triangulation, hole filling, triangular mesh.

1. INTRODUCTION

For object representation, it was important that the surface was error-free. However, there is occurrence of undesired holes due to accessibility limitation pertaining to scanning devices. Such undesired holes impact both the model visualisation as well as render unexpected results pertaining to applications like rapid prototyping, segmentation and finite element analysis. Therefore, it is important to get in place semiautomatic or automatic methods in order to fill the holes pertaining to the surface of the 3D object. This step is important in order to achieve a high quality mesh model as well as retrieve complete geometric information. This process was also can been seen on the latest research on image processing and data reconstruction for real life object[1-3].

The characteristics include hole filling that can be segmented into two categories. One pertains to geometric detail or texture structures, like geometric details pertaining to a hair region on a head. The other one pertains to sharp characteristics, like corners or sharp edges in Computer Aided Design (CAD) modelling. In order to reconstruct geometric details pertaining to the missing holes, various methodologies have been put forward [4-10]. With regards to context-based methods[11,12]or example-based methods[13-15], iterative filling of the holes is carried out by copying similar matching patches from the existing models or from the input model itself. A mapping between a template model and the incomplete mesh was first computed by Kraevoy et.al [16] , which was then used with this mapping to stick together all the components pertaining to the input mesh as well as to fill the holes at the same time. 3D geometric information of holes was reconstructed by Nguyen et.al[17] by synthesising local gradient images pertaining to the 2D parametric domain. A texture synthesis and context based approach was put forward by Xiao et. al [18] for appearance as well as geometric completion pertaining to point set surfaces. In recent times, Li et al [16] designed a skull completion approach by conjoining symmetric detection as well as template-based method.

Chen et. al [19] used a sharpness-dependent filter to fill the holes and recover sharpness. The filter works through distribution of the sharpness values pertaining to triangle faces that are present near a hole boundary. In a similar manner, the vicinity pertaining to a hole boundary can be defined by its two-ring neighbourhood. For any triangle face, computation of its sharpness value is done based on the variance pertaining to the angles between its normal and each of the normals pertaining to the neighbouring faces.

To fill the holes, Chen and Cheng [20] put forward a sharpness-based approach. The entire algorithm has been carried out in two steps: an interpolation step that includes filling the hole that yields the approximation pertaining to the final model as well as a post-processing step that can modifies the approximation model in order to match with the original. Interpolation of the hole patch is done by employing the radial basis function in order to produce a smooth implicit surface that allows filling up the holes. A regularised matching tetrahedral algorithm is employed to triangulate the implicit surface. After which, stitching of the triangulated surface patch to the hole boundary is carried out in order to construct the repaired model. During the post-processing steps, for this repaired model, a sharpness dependent filter is applied for recovering the sharp characteristics. In this research work, sharpness dependent filter has been employed, which is an improvement on the one put forward by Chen et.al [21]. The system is challenging to implement even though this algorithm seems to function effectively for model repairing.

It is still a difficult task to handle the fine features at the hole areas even though an automatic system is always looked for. In the paper by Zhat et. al [22], a complicated hole-filling optimisation engine has been employed to achieve the results automatically. However, recovering of the fine characteristics is not always sufficiently achieved in many cases. A majority of the systems need user intervention to determine the best guess pertaining to fine characteristics near the hole areas as well as to rectify the automatic results.

In this research work by Ohtake et. al [23], a multilevel piecewise surface fitting approach has been used for preserving the shapes pertaining to sharp edges and corners near the hole sites in order to represent a mesh model containing fine structures. The piecewise quadric surface fitting approach has been employed for local approximation pertaining to fitting edges as well as corners. It includes numerous tests (corner and edge tests) for identifying the kind of approximation surface or which shape function needs to be employed. The normals pertaining to the mesh vertices are clustered in order to automatically recognise corners and edges.

Sharf et. al [24] put forward a context-based completion approach in order to recover the missing fine details pertaining to a repaired hole. This approach is based on the concept of texture synthesis, in which portions of regions are replicated from suitable examples. By employing this concept, recovering of the fine structure pertaining to the 3D model is done by identifying a piece in the original model or in template models possessing similar shapes in order to substitute the initial repaired hole. Thus, this approach is regarded to be efficient when repairing holes pertaining to the textured mesh model.

Attene et. al [25] put forward a method for recovering the sharp characteristics pertaining to the 3D mesh model, which could have been lost by the remeshing processes or by reverse engineering employing a non-adaptive sampling pertaining to the original surface. In the mesh model, the algorithm begins by recognising the smooth edges, after which the filters are used for obtaining chamfer edges. New vertices are inserted for each of the chamfer edge as well as for segmentation of its incident triangles. Calculation of these vertices is done to ensure that they fall within the intersections of planes and it also helps in local approximation of the smooth surfaces meeting at the sharp characteristics.

For hole-filling, He and Chen [26] used both interactive and automatic methods. Also, a novel hole-filling system has been put forward that employs a haptic device. Post the hole identification phase, the interpolation step focuses on smoothing the hole boundaries. This step helps in rectifying boundary topologies as well as fixing the boundary edge lengths to make sure that there is no uneven distribution of points near the hole boundary. After this, in the stitching process, such complex holes can be decomposed by the user into simpler ones. Regular triangulation approaches are employed to automatically triangulate sub-holes. Also, the intervention process can be repeated by the user until satisfactory results are achieved. An interesting idea was put forward by the authors regarding haptic for 3D user intervention. However, this method cannot automatically identify the fine characteristics pertaining to the mesh, which also serves as guidance for the user.

Zhap et. al [27] identified the holes and then employed the modified minimum-weight triangulation technique for triangulation. Crest line fairing is employed to recover sharp characteristics. In this research work, the crest line detection technique [28] is employed by the system to identify the feature line pertaining to the original mesh. Crest lines can be defined as the salient surface characteristics pertaining to the first and the second order curvature derivatives. Then, crest lines that are detected are employed in region growing and fairing processes for recovering the sharp characteristics near the hole areas. Prior to the region growing step, the users can connect to some crest lines. The issues that have been concentrated on the research pertain to the corner of triangle or are also referred as missing characteristics pertaining to the triangle. It puts forward a new hole filling algorithm that also allows recovering the original shape pertaining to the hole region by employing the hole neighbourhoods' geometric information. The advancing front mesh method was employed for the hole triangulation.

The problems focused for the research was on the corner of triangle or also known as missing features on the triangle. It presents a new hole filling algorithm which could recover the original shape of the hole region by using the hole neighborhoods geometric information. The hole triangulation was achieved by advancing front mesh method. The remainder of this paper is organized as follows : Section 2 show the classification of data. Section 3 shows preprocessing process until choosing hole to fill. Section 4 shows the Enhanced method for AFM. Section 5 shows some experimental results. Section 6 is the conclusion of this paper.

2. CLASSIFICATION OF DATA

In this research paper, the employed 3D object was three pronged, i.e. Subject 1, 2 and 3 as listed in Table 1 below. Subject 1 pertains to the back view characterised by the shining blue body possessing a black mouth as well as a green roller coaster along with orange tyre. Subject 2 is denoted by a can possessing a back view with regards to the cylindrical shape body along with an L-shaped top. Subject 3 is represented by the yellow can that has a colourful design on the object's front view. The right and left sides of the can also had some curves on them. Figure 1 below showcases all the Subjects.

Table 1: Classification of Subject

Subject Number	Subject
1	Rio (4^{th} view)
2	Spray (4^{th} view)
3	Mentos(1^{st} view)

(a)

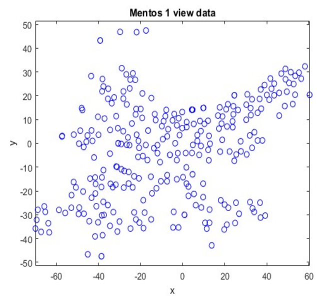
(b)

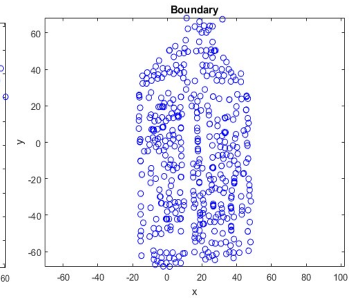
(c)

Figure 1: Subject in 3D
(a) Subject 1 (b) Subject 2 (c) Subject 3

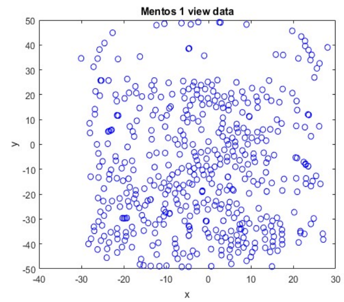
For all the subjects, the control point is required to be clean prior to using it for any reconstruction. However, some issues could occur like noisy data point, repeated data points and data points that are in proximity to each other. In processing the data point, the very first step would be to determine the unique data also called as the data point that is similar. Then, deletion of the unique data point is done in order to ease the process for filling later.

In this research, the original control point employed for the three Subjects has been shown in Figure 2. Subject 1 had a total of 312 data points for the front view and post deletion of similar (unique) points, the total reduced to 303 data points. A total of 557 data points were found with Subject 2 and post the deletion step, the count reduced to 530 control points. On the other hand, Subject 3 had 589 control points, which became 564 control points post the deletion step.





(a) (b)



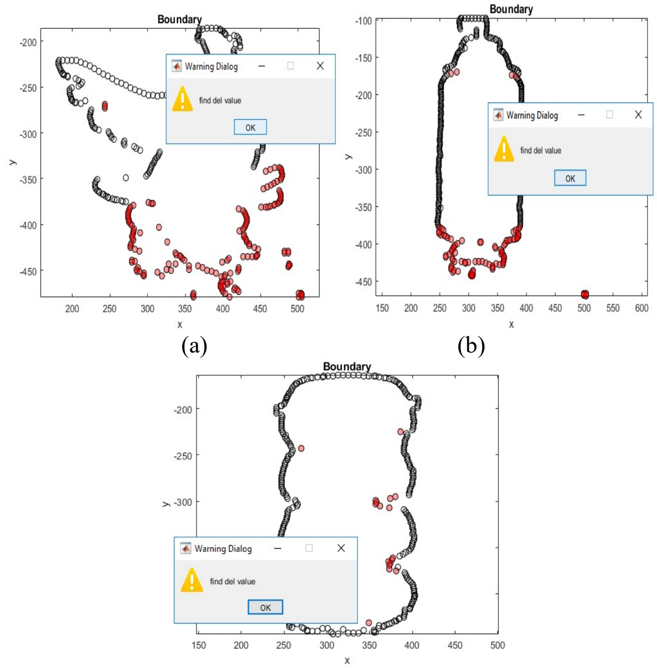
(c)

Figure 2: Control Point for Subject
(a) Subject 1 (b) Subject 2 (c) Subject 3

3. BOUNDARY IDENTIFICATION

The boundary of the Subject was determined by using Canny edge detection that would find all the edges in an image. It employed double threshold for finding out potential edges, the lower and upper threshold. It was broadly employed for the comparison of other techniques as it would give good results. Then, the scanline algorithm technique was employed for the extraction of the outer boundary. The columns and rows of the image were approximated by the method, namely the scanline and results pertaining to a boundary of points.

However, the user will have to delete certain point that is inside the object or located far from the boundary due to which the boundary is not represented properly as shown in below highlighted in red. Figure 3(a) presents the result pertaining to the approximate data from edge detection as well as scanline by Subject 1. The boundary colour is in black, while the red data points that are considered outlier are required to be deleted. The point has to be deleted in order to avoid point overlap when constructing the boundary. As per Subject 2 on Figure 3(b), some points were found to be far from boundary and the spray boundary's bottom needs to be deleted as it was very much scattered. As per the results from Subject 3, only few points were deleted as these overlapped with other points as shown in Figure 3(c).



(a) (b)

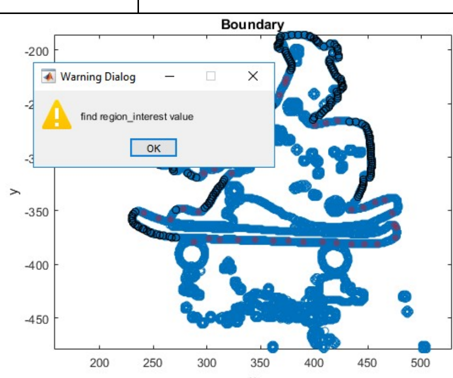
(c)

Figure 3: Delete Outlier
(a) Subject 1 (b) Subject 2 (c) Subject 3

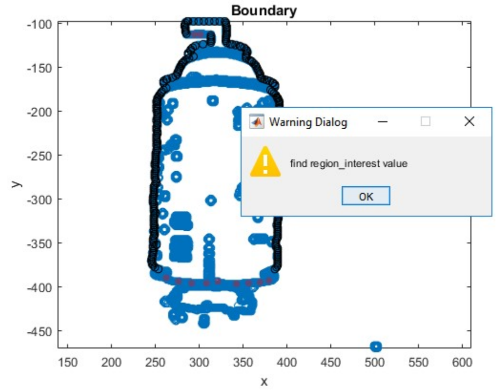
A situation also occurs in which employing Canny edge detection and scanline algorithm cannot represent certain characteristics. As presented in Figure 4, threshold method was employed to demonstrate the missing feature pertaining to certain objects. The functioning of the threshold method occurs by changing the background colour to either more white or black in order to represent the missing characteristics. The point that is missing can be chosen by the user and the point can be added to the boundary.

Table 2: Delaunay Triangulation of Subject

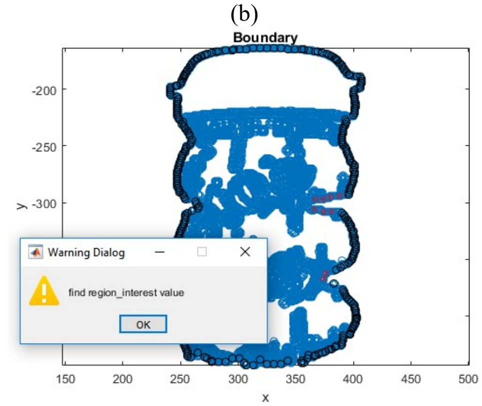
Subject Number	Connectivity List
1	590x3
2	1040x3
3	1111x3



(a)



(b)

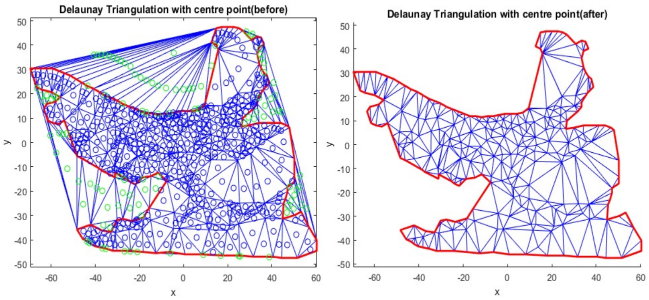


(c)

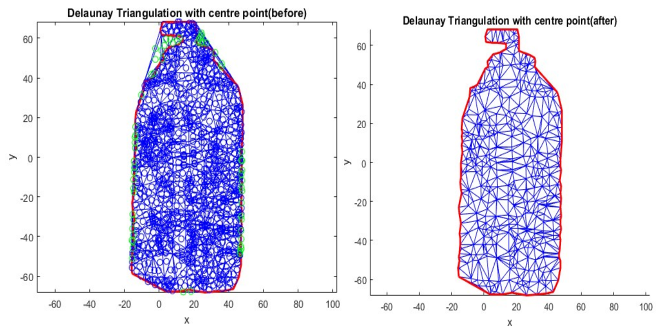
Figure 4: Threshold method
(a) Subject 1 (b) Subject 2 (c) Subject 3

The boundary results obtained from all the processes above pertaining to all Subjects can be employed to represent the Subject completely. For representing the object in a triangular mesh, we employed the Delaunay triangulation. Delaunay Triangulation was created by selecting the Fortune's algorithm that is based on sweepline algorithm. The method was selected as it is simple as well as easy to adopt. Delaunay is regarded as the best method for representing the objects in a triangular mesh as it includes all characteristics of data point as well as connectivity list that could be employed at a later stage of 3D reconstruction. This is represented in Table 2. Delaunay Triangulation was employed to obtain information from all the three subjects.

For all the Subjects, Delaunay Triangulation with no constraints was designed. Boundary that was obtained from the above process could be employed as constraints pertaining to each Subject that is used. The step involved calculation of the centre pertaining to the entire triangle by employing mean of (x,y), followed by the deletion of the centroid of triangle (green data point) that is towards outside of the red line's boundary. Figure 5 demonstrates the before and after constraint pertaining to Delaunay triangulation that was employed for all Subjects.



(a)



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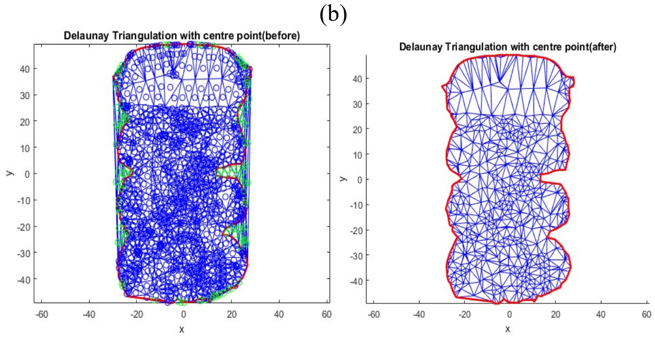
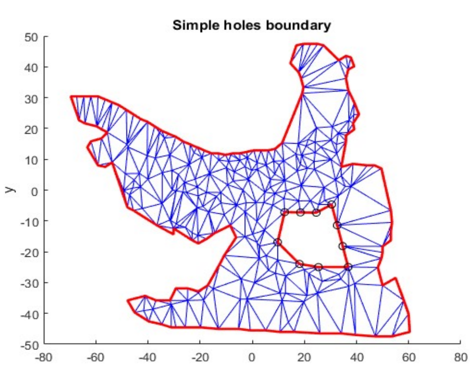


(c)

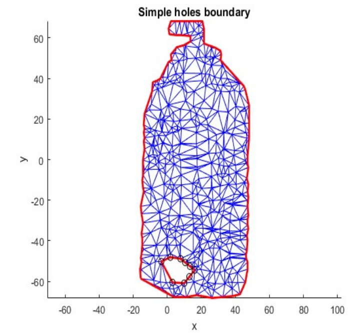
Figure 5: Constraints Delaunay Triangulation
(a)Subject 1 (b) Subject 2 (c) Subject 3

4. HOLE IDENTIFICATION

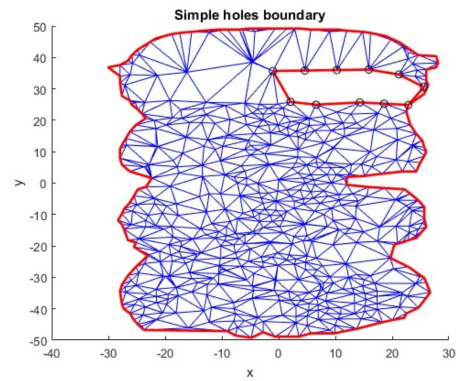
Now the next step was the selection of the boundary of holes by the user. The maximum area pertaining to all the triangles was regarded as holes, which have been defined via green data points while the other points with the blue data point. Figure 6 shows the result pertaining to all holes for the Subject.



(a)



(b)



(c)

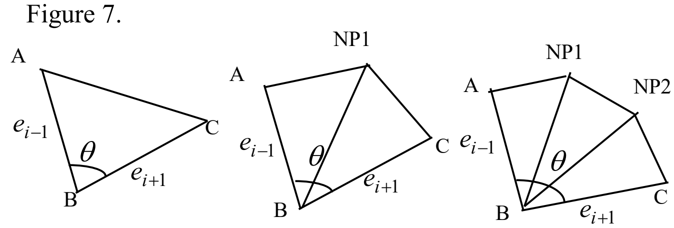
Figure 6: Holes for Subject
(a)Subject 1 (b) Subject 2 (c) Subject 3

5. ADVANCING FRONT MESH (AFM) METHOD

In this research, advancing front mesh (AFM) method was a technique used to fill holes with a triangle and it involved six important step as follows [22].

Step 1: Identify three points as the starting point define as boundary of holes and defined as point A, B and C.

Step 2: Calculate angle θ_i between the edges AB and BC as Figure 7.



(a) (b) (c)

Figure 7: Three Rules of angle in AFM
(a) $\theta \le 75^0$ (b) $75^0 < \theta < 135^0$ (c) $\theta \ge 135^0$

Step 3: The triangle was created according to the three different criteria shown in Figure 7. The explanation for each degree was as follows:

(a) If $\theta \le 75^0$,only one triangle created as point A and C was connected (Figure 7(a)).

(b) If $75^0 < \theta < 135^0$, two triangle were formed and one new point created label as NP1 in Figure 7(b).

(c) If $\theta \geq 135^0$, three triangle $\Delta ABNP1$, $\Delta NP1BNP2$ and $\Delta NP2BC$ were formed with two newpoint NP1 and NP2 and label in Figure 7(c).

Step 4: Next process of searching nearest point, threshold was use where distance between new point and B was used $\overline{NP1B}$

$$Threshold = \frac{1}{4} \times (\overline{NP1B}) \quad (1)$$

Step 5: Update the control points
Step 6: Repeat step 1 through step 4 until the whole region of holes has been created and fill with triangle

However, when the original AFM method was employed, an issue occurred when creating the triangle on the corner of a hole. This issue had particular occurred near the corner of hole in which there was no connection of the point with any of the nearest active point by employing threshold radius. Thus, the issue called as missing features that occurred on a corner of a hole was solved by employing the new algorithm. In this research paper, the point that was created by employing AFM has been labelled as point PT, while the point post employing EAFM was labelled as NP. This helped in simplifying the explanation for the process in the later section.

Algorithm (Step 5)

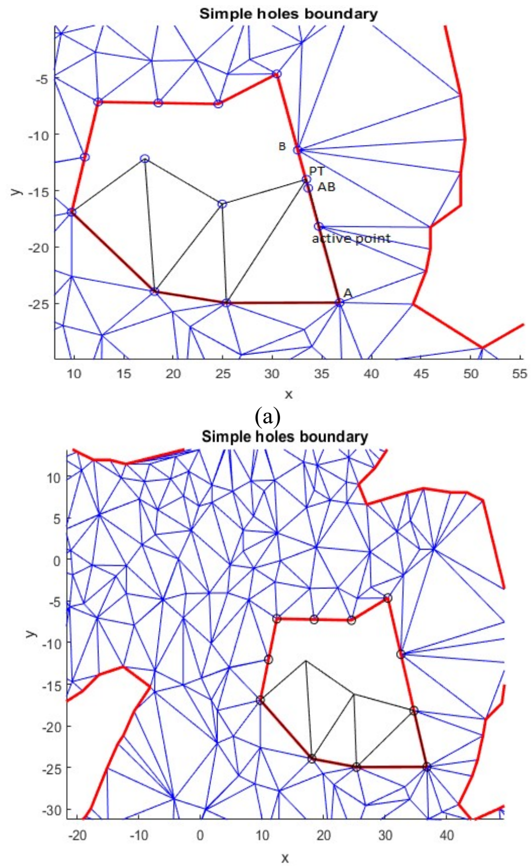
1. Identify the PT point between the line segment
2. Calculate the midpoint (AB) between two end point on the line segments
3. Calculate Dist1 = distance PT to the nearest active point
   Dist2 = distance AB to the nearest active point

if Dist1 > Dist2
    PT considered to be NP
else Dist1 > Dist2
    AB considered to be NP
end

SUBJECT 1

Figure 8 shows the problem associated with Subject 1, after using the advancing front mesh method (AFM), the point PT was created and bisecting the line. However there it is at a significant distance from the previous active point which not used yet. The enhanced algorithm was employed to deal with this problem. In the case of Subject 1, the solution is by identifying point PT and calculating the mid-point (AB) between the two closest active points A and B as in Figure 8(a).

The distances between point A to both point PT and AB were measured and compared. It was found that distance of PT was higher than AB. PT should be the new point; however, the situation was different because the previous active point had not been used yet. Therefore, the previous active point was considered to be the NP. For Subject 1, Fig 8 (b) shows the obtained results.



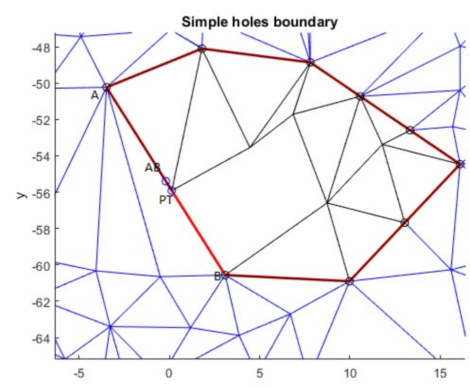
(a)

(b)

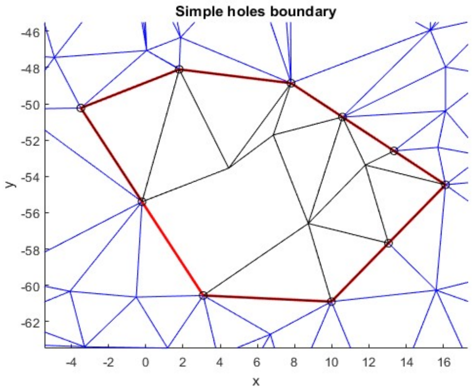
Figure 8: Result of Subject 1
(a) Apply by AFM(b) Apply the Enhanced Method

SUBJECT 2

In the case of Subject 2, the challenge is that an active point is not present near PT. Therefore, it was required to identify whether PT was present on the line segment. In case it was not, a perpendicular bisector would be required to identify such a point. In this case, the enhanced method was utilised to calculate the distances between point A and the two points AB and PT. Since PT was situated at a greater distance, it was considered to be NP. Figure 9 highlights the results before and after the application of the enhanced method.



(a)

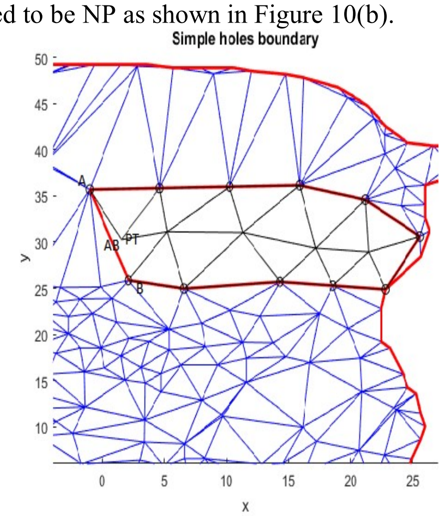


(b)

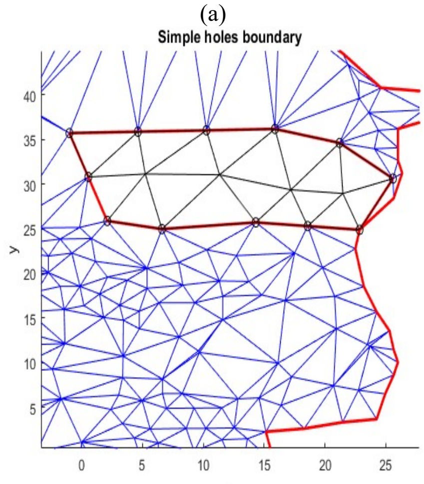
Figure 9: Result of Subject 2
(a) Apply by AFM(b) Apply the Enhanced Method

SUBJECT 3

In case of Subject 3, PT does not bisect the line, and there is a lack of any point where it was created (Figure 10(a)). The midpoint(AB) was determined, In this problem, AB was considered to be NP as shown in Figure 10(b).



(a)

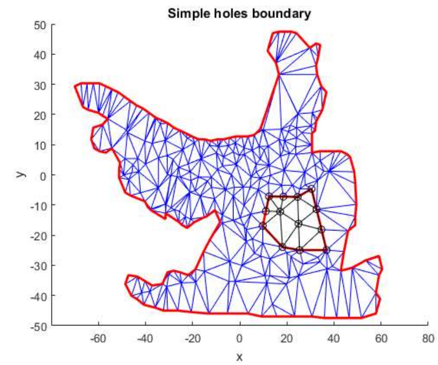


(b)

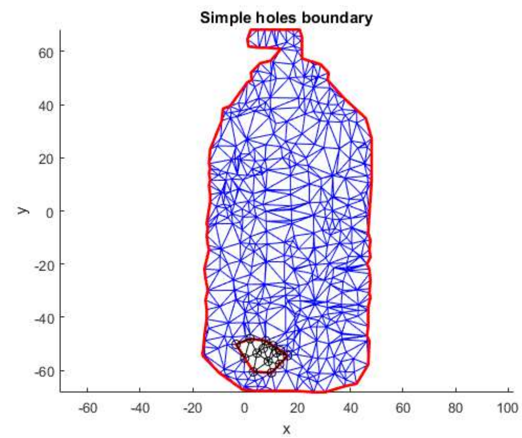
Figure 10: Result of Subject 3
(a) Apply by AFM(b) Apply the Enhanced Method

FINAL RESULTS

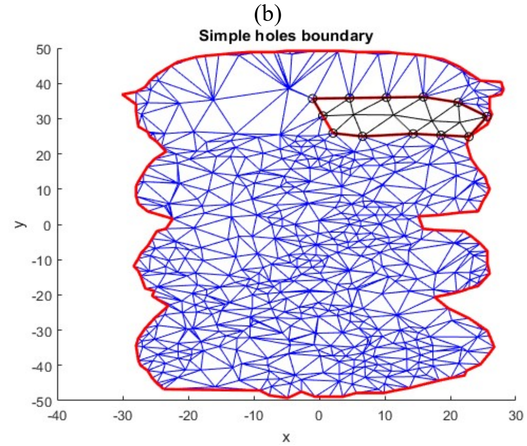
Figure 11 highlights the results obtained in the process of filling holes using the enhanced method, AFM, on the three Subjects. Table 2 documents the running time and the results prior to and after filling the holes.



(a)



(b)



(c)

Figure 11: Final Result
(a) Subject 1 (b) Subject 2 (c) Subject 3

Table 3: Result before and after for all Subject

Subject Number	Number of vertices		Number of Triangle		Running Time
	Before	After	Before	After	
1	303	306	590	603	75.3281
2	530	534	1040	1056	45.3594
3	564	569	1111	1129	54.1719

6. CONCLUSION

In this chapter, three objects were utilised as tests for points missing on the corner of holes. Before addressing the issue of filling the holes, some pre-processing was performed, and it was identified that Subject 1 had significantly more missing boundary than the other two subjects. This paragraph sums up the current chapter. Processing time was higher for Subject 1(Table 3), given the complex nature of the object. Since the Delaunay Triangulation for all three subjects was set without any constraints, it was necessary to identify the boundaries. In this three object model, problems were identified while filling the holes. The challenge was in identifying whether the created point was bisecting the line. Except for Subject 3, the point was found to be bisecting the line. The enhanced method was an improvement of the original model and was used in three different scenarios. Given that the holes do not have a point, an increase in the number of triangles and vertices is observed. The introduction of points in holes helps represent better the features of the object. Subject 3 was observed to have the most significant increase where the vertices and triangle count saw a rise. The running time has been the lowest despite the increase in vertices and triangle owing to the lower number of points required to represent the boundary.

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REFERENCES

1. L. Praneetha S.K , A.K , G. Viharika R, D. Sree M and V. P.**Automated Leaf Disease Detection in Corn Species through Image Analysis,** *International Journal of Advanced Trends in Computer Science and Engineering,*Volume 8, No.6, pp. 2893-2899,2019 https://doi.org/10.30534/ijatcse/2019/34862019
2. Dr.A.Nagarajan and J. V. Wason. **Machine Learning Approach to Predict Lung Cancer using CT scan Images,** *International Journal of Advanced Trends in Computer Science and Engineering,*Volume 8, No.6, pp. 2974-2976,2019. https://doi.org/10.30534/ijatcse/2019/48862019
3. J.Ade , A. Ali ,S. ,A. K. Rayza, E.Latifah, N.Endang and W.Teguh .**Representation Learning for Dental Image Identification,** *International Journal of Advanced Trends in Computer Science and Engineering,*Volume 8, No.6, pp. 3476-3480,2019. https://doi.org/10.30534/ijatcse/2019/124862019
4. L. Yang, Q. Yan and C. Xiao. **Shape-controllable geometry completion for point cloud models,** *The Visual Computer*, 33(3), pp. 385-398,2017.
5. Hsi-An Chiao Tung Ta Hsueh. **Rapid Mesh Hole Filling in Body Model**, *Journal of Xi'an Jiaotong University*,52(8), pp.37-42, 2018.
6. X. Wang,J. Hu, D. Zhang, L.Guo,H. Qin, and A.Hao. **Multi-scale geometry detail recovery on surfaces via empirical mode decomposition**,*Computers & Graphics*, 70, pp. 118-127,2018.
7. N.Luo, and Q.Wang. **Fast self-repairing region growing surface reconstruction algorithm for unorganised point cloud data**, *International Journal of Computer Applications in Technology*, 56(2), pp. 121-131,2017.
8. K. M.Tran and M. H. Tran. **Filling Hole on the Surface of 3D Point Clouds Based on Reverse Computation of Bezier Curves**, *In Information Systems Design and Intelligent Applications,Springer, Singapore*, pp. 334-34,. 2018.
9. S.Zhao, W. Zhang, W.Sheng and X. Zhao. **A Frame of 3D Printing Data Generation Method Extracted from CT Data**, *Sensing and Imaging*, 19(1), 12,2018. https://doi.org/10.1007/s11220-018-0197-8
10. S. Setty and U. Mudenagudi. **Example-based 3D inpainting of point clouds using metric tensor and Christoffel symbols**, *Machine Vision and Applications*, 29(2), pp: 329-343.
11. A.Sharf,M.Alexa,D.Cohen. **Context based surface completion**, *ACM TransGraph23*,pp.878–887,2004.
12. S.Park,X.H.Guo,H.Shin and H.Qin. **Surface completion for shape and appearance**, *VisComput22*, pp.168–180, 2006.
13. J.Podolak,S.Rusinkiewicz. **Example based 3d scan completion**, *in SGP'05:Proceedings of the Third Eurographics Symposium on Geometry Processing*, pp.23–32,2005.
14. G.H.Bendels,R.Schnabel and R.Klein. **Detail preserving surface inpainting**, *in The 6th International Symposium on Virtual Reality,Archaeology and Cultural Heritage(VAST)*,pp.41–48,2005.
15. T.P.Breckon and R.B.Fisher. **Three-dimensional surface relief completion via nonparametric techniques**,*IEEE Trans Pattern AnalMach Intel*l,30(12),pp.2249–2255,2008.
16. V.Kraevoy and A.Sheffer. **Template based mesh completion***, in SGP'05:Proceedings of the Third Eurographics Symposium on Geometry Processing*,pp.13–22,2005.
17. M.X.Nguyen,X.-R.Yuan and B.Q.Chen. **Geometry completion and detail generation by texture synthesis**, *VisComput21*, (9–10), pp.669–678,2005.
18. C.X.Xiao,W.T.Zheng,Y.W.Miao,Y.Zhao and Q.S.Peng. **A unified method for appearance and geometry**

completion of point set surfaces, *Visual Comput23*, pp.433–443,2007.

19. X.Li, Z.Yin, L.Wei, S.H.Wan, W.Yu and M.Q.Li. **Symmetry and template guided completion of damaged skulls**, *ComputGraph35(4)*, pp.885–893, 2011.
20. C.Y.Chen and K.Y.Cheng. **A sharpness dependent filter for mesh smoothing**, *Comput Aided Geom Des22(5)*, pp.376–391, 2005.
21. C.Y.Chen,K.Y.Cheng, **A sharpness dependent filter for recovering sharp features in repaired 3d mesh models**,*IEEETransVisualComputGraph14(1)*,pp.200–212,200. https://doi.org/10.1109/TVCG.2007.70625
22. W. Zhao,S. Ghao and H.Lin. **A robust Hole filling algorithm for triangular mesh**, *Journal of the Visual Compute*r,*International Journal of Computer Graphic*s,23(12),987-997,2007.
23. Y. Ohtake, A. Belyaev, M. Alexa, M.Turk,G. Seidel. **Multi Level Partition of Unity Implicit**, *Journal of ACM Transaction on Graphics(TOG), Proceedings of ACM SIGGRAPH 2003,22(3)*,pp.463-470,2003.
24. A.Sharf, M. Alexa and D. Cohen. **Context-based Surface Completion**, *Journal of ACM Transactions on Graphics-Proceedings of ACM SIGGRAPH 2004*,23(3),2004.
25. M. Attene,B. Falcidieno,J. Rossignac and M. Spagnuolo. **Edge-Sharpener: Recovering Sharp Features in Triangulations of Non-adaptively Re-meshed Surfaces**: *In Proceedings of the First Eurographics Symposium Geometry Processing (SGP 2003),Eurographics Association, Aire-la-Ville*,pp. 63-72,2003.
26. X.J He and Y.H Chen. **A Haptics-guided Hole Filling System Based on Triangular Mesh**, *Computer Aided Design and Application*,3(6),pp.711-718,2006.
27. M. Zhao, L.Ma, Z. Mao, Z.Li. **Feature Sensitive Hole Filling with Crest Lines**, *In:L.Jiao,L. Wang,X. Gao,J.Liu,F.Wu(eds.)ICNC2006.LNCS,vol.4222*,pp.660-663.Springer,Heidelberg,2006.
28. S. Yoshizawa, A. Belyaev, H. Yokota and H.P Seidel. **Fast and Faithful Geometric Algorithm for Detecting Crest Lines on Meshes**, *In: Proceedings of the 15th Pacific Conference on Graphics Applications, Computer Graphics, Washington*, DC, pp. 231-237,2007. https://doi.org/10.1109/PG.2007.24