Transactions on Mechatronics

Decision Letter (TMECH-01-2022-13137)

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Subject: TMECH-01-2022-13137 - Transactions on Mechatronics

Body: 16-Mar-2022

Dear Dr. Wang:

Your manuscript submitted to the IEEE/ASME Transactions on Mechatronics,

ID: TMECH-01-2022-13137
Title: Non-revisiting Uniform Coverage by Edge Subdivision of Arbitrary Meshes
Paper Type: TMECH/AIM Focused Section Papers

has been reviewed by the Technical Editor and/or selected Reviewers. Their comments and suggestions are below and/or in separate files which may be accessed by going to your Author Center. On the basis of the review comments and ratings, I regret to inform you that your manuscript cannot be published in the Transactions.

Please note, as a submission to the TMECH/AIM Focused Section on Emerging Topics, your manuscript will be automatically transferred to the next IEEE/ASME AIM Conference for their independent review as a Contributed Conference Paper.

We thank you for your interest in the IEEE/ASME Transactions on Mechatronics and hope that you will consider publishing future papers here.

Sincerely yours,

Dr. I-Ming Chen :: Professor :: Editor-in-Chief, IEEE/ASME Transactions on Mechatronics :: Fellow of Academy of Engineering, Singapore :: Fellow of IEEE :: Fellow of ASME :: School of Mechanical and Aerospace Engineering :: Nanyang Technological University :: 50 Nanyang Ave, Singapore 639798

Senior Editor: 1
Comments to the Author:
Unfortunately, both Guest Editor and Reviewers think the paper is not ready to be considered for TMECH publication. Please refer to their comments to improve the paper.

While the paper is not accepted for TMECH publication, it will be considered further by AIM 2022 as a contributed conference paper.

Technical Editor: 2
Comments to the Author:
The paper proposes a uniform non-revisiting uniform coverage approach for non-planar surfaces. The proposed approach is simple and interesting, but lack of theoretical contribution and sufficient experimental validation. Major concerns are as follows:
1. Theoretical contribution is minor due to the following two reasons: (1) The proposal lacks in depth formalization to general cases rigorously; (2) The existence of the non-revisiting coverage path is claimed to be proved. However, there is a lack of a formal proof.
2. The relevance from the point of view of the application is reduced due to the practical issues such as the trajectory smoothness, the kinematic constraints of manipulators, etc.
3. The comparison study and the number of tested object surfaces are not sufficient.

According to the comments, the paper's contribution cannot achieve the standard of IEEE/ASME Transactions, and many works still need to be strengthened.

REVIEWERS' SUGGESTIONS:

Reviewer: 1
WHAT ARE THE CONTRIBUTIONS OF THIS PAPER: This work proposed a mesh-model-based coverage path planning (CPP) mechanism for manipulators to achieve the non-revisiting uniform coverage (NUC) of arbitrary surfaces, which is important for some practical applications. Some simulation and experiment results are presented to prove the validity of the proposed method. In addition, an open-source implementation is released for the research community.

Reviewer: 2
WHAT ARE THE CONTRIBUTIONS OF THIS PAPER: The contribution of this paper resides on the algorithm that finds a geometric coverage path by constructing a non-revisiting route on a given mesh.

Reviewer: 3
WHAT ARE THE CONTRIBUTIONS OF THIS PAPER: This paper proposes an algorithm to generate a non-repetitive path for surface coverage. The proposed algorithm is verified with simulations and an experiment.

Reviewer: 1
WHAT ARE SOME WAYS IN WHICH THE PAPER COULD BE IMPROVED: 1. An in-depth and solid simulation study is required in advance.

2. The proof of the existence of the NUC in arbitrary surfaces should be provided formally.

3. The references of the manuscript should be reordered.

Reviewer: 2
WHAT ARE SOME WAYS IN WHICH THE PAPER COULD BE IMPROVED: See comments to the author.

Reviewer: 3
WHAT ARE SOME WAYS IN WHICH THE PAPER COULD BE IMPROVED: An experiment with a UR5 robot is used to show the performance of the proposed algorithm but only a small part of the surface area is covered in both the generated path shown in Fig. 12 and the video. Although the paper mentions that some constraints are considered when creating the path, it is better to show the targeted area and the region that has been covered, otherwise, the readers may be confused. In addition, since the coverage rate in the simulation is always less than 100% but the coverage path is too dense to view the missing part, it would be better to highlight the uncovered regions.

In the contribution, it says that no cellular decomposition process is required in the proposed method. However, the algorithm first remeshes a surface into uniform facets is also counted as cellular decomposition.

The paper can be reorganized to make the proposed method easy to follow. For example, Algorithm 1 takes almost half a page without any explanation of the algorithm. In addition, Algorithm 1 is mentioned on Page 6, but it shows on Page 4.

The writing of the paper can be improved. Some references are noted as [?]. There are some grammatical errors such as sentence fragments as the second sentence in III. B. In related works, both present and past tenses are used. In the problem modeling section, both present and future tenses are adopted. It could be better to make the tense consistent throughout each section. For a figure with multiple subfigures, it would be clearer to have subtitles. The font subtitle in Fig. 2 is too small. Then indentation of the line after Fig.2's title is incorrect.

Reviewer: 1

Comments to the Author
This work proposed a mesh-model-based coverage path planning (CPP) mechanism for manipulators to achieve the non-revisiting uniform coverage (NUC) of arbitrary surfaces, which is important for some practical applications. Some simulation and

experiment results are presented to prove the validity of the proposed method. In addition, an open-source implementation is released for the research community. Overall, the work is interesting. However, the paper has several shortcomings that need to be addressed before publication.

Major concerns:
1.1 The authors emphasized in the contribution section that they have proved the existence of the NUC in arbitrary surfaces, but the reviewer does not see any formal proof of that.

1.2 The authors claimed in the contribution section that they have proven that their method does not need a cellular decomposition process. However, the step 1 (i.e., Subdividing the Mesh) of the proposed method is also a "cellular decomposition" process in some ways. I would suggest making this claim weaker.

1.3 Even though some simulation and experiment results have been demonstrated, only one comparative trial is conducted on one simple saddle surface. It is not enough to validate the performance of the proposed method.

1.4 The simulation study is not compared with enough previous works. Is there only the Boustrophedon- or spiral-based method for the CPP problem that can achieve nonrepetitive coverage of the target surface? These two methods are too old and too classical. An in-depth and solid simulation study is required in advance.

1.5 Why non-revisiting coverage is important? and what advantages can it provide? It should be explained clearly and early in the introduction section.

1.6 Why the mentioned methods, i.e., Boustrophedon, spiral and NUC, can not achieve 100% coverage? They are all planning coverage paths by assigning the waypoints of the tool as the center of the grid of the mesh and the size of the grid is determined according to the tool size. Consequently, the target surface can be fully covered by visiting these grids one by one in a back-and-forth manner without revisiting. Moreover, the authors have stated that "the non-revisiting uniform coverage (NUC) task is defined as finding a non-selfcrossing tool path that will visit "all the points" uniformly distributed on the surface". Therefore, the NUC can achieve full coverage at least. However, the experimental results presented in Section V show that full coverage is not guaranteed.

1.7 How do you guarantee the feasibility of the kinematics of the manipulator when they are tracking the NUC path? It is not mentioned in the manuscript that your method has considered the kinematics when planning the coverage path.

1.8 Since the paper proposed a model-based CPP mechanism, the modeling error of the target mesh may affect the step 1 of the method and further result in failure in the step 2. Therefore, how do you handle the modeling errors in the planning process?

Minor concerns:
2.1 The references of the manuscript are unordered and there are even some mistakes in Section II. In addition, the format of the references should be revised carefully to meet the journal's requirements.

2.2 In the last of Section II, some conclusive comments can be made based on the reviewed literature. This can help readers to quickly pick up the differences between your work and the existing ones.

2.3 What is the symbol "%" meaning in the line1/line3 of the Algorithm. 1? Please elaborate it.

2.4 In section V, apart from experimental results, substantial content on simulation results have been presented. So the title of Section V looks to be incomplete and incorrect.

Reviewer: 2

Comments to the Author
The goal of this work is to compute a linear path over a 3D surface to perform uniform coverage avoiding overlaps and missing gaps. In the definition of the problem, the authors consider a realistic tooling size, which needs a particular strategy to obtain a

set of uniformly distributed points on the object mesh surface. The main steps consist in an appropriate uniform mesh computation and then, the proposed algorithm finds a non-revisiting path by edge subdivision of an initial mesh and path deformation to obtain a continuous path ensuring full coverage.

The presentation of the submission is correct. I liked reading the paper, it is easy to follow and well written. There are some typos an grammatical mistakes. The related work survey seems correct although there are some question marks in the text referring to unknown references. Please check citations. For example you refer to Meshlab with [34], which is incorrect, and other references are never cited.

The contribution of this paper resides on the algorithm that finds a geometric coverage path by constructing a non-revisiting route on a given mesh. Although the considered problem is worth of interest, the proposed contribution seems minor from a theoretical point of view. The proposal lacks in depth formalization or perhaps the complexity level of the contents is not enough to require that formalization. Additionally, the relevance from the point of view of the application is reduced due to the practical issues, commented below, about smoothness, overlapping or adequate validation. Therefore, I consider this paper's contribution is minor.

In the problem statement, the number of points to be uniformly distributed on the surface is computed as the area of the surface divided by Pi times square radius of the tool. I think that this number should be an integer, and I am not sure if you are considering overlapping or free space between tool circles. Perhaps this number is just a rough estimation. Clarification is needed.

Since the computed path can be a little contorted over the object surface, I am not sure about the applicability of this method in typical scenarios where the smoothness of the trajectory is a must.

The size of the tool is intrinsically related with the size of the facets of the mesh. I think it is necessary to detail how is decided the size of the triangles of the mesh taking into account the tool's radius. Especially since the edge subdivision step will reduce the size of the mesh grid. In that case, following the computed path would produce higher overlapping.
The existence of the non-revisiting coverage path is claimed to be proved. However, there is not a formal proof. In general it is reasonable that the path will be found, but playing with the size of the mesh facets and the size of the tool could be problematic. For example, acute parts of the object can make impossible to find a round trip. Perhaps the problem definition can make some assumptions to avoid these issues, but this requires a more in depth formalization.

The proposed method is evaluated in simulation and with a real robot. The results are good to understand the main idea of the proposal but lacks proper validation. The performance of the results is measured with the percentage of the coverage of the method compared with others. However, it is necessary to provide other metrics. For example, it could be computed the time to fulfill the task, or the overlapping of each method (in percentage wrt to the area). Moreover, the computation of the area covered is done with the multiplication of the length of the path by the diameter of the tool. I think it could be more precise to integrate the real covered area. Otherwise, if I interpret correctly the results, the contorted path obtained with the proposed method benefits of this metric with respect other approaches. Additionally, the quality of the obtained path is not evaluated in terms of quality. What about the required speed and the quantity of turns? Does it affect to the performance in a real system? Usually, smooth motion of the tool is important for the quality of the result. It seems that there are many back and forth motions. Maybe a hybrid approach could add some value from a practical point of view. In figure 9, that shows the resultant path of the method in the saddle example, I missed the plots of the circular markers of the tool, to see in the top view the overlapping and the empty spaces.

Reviewer: 3

Comments to the Author
Please refer to the section "WHAT ARE SOME WAYS IN WHICH THE PAPER COULD BE IMPROVED?".

Date Sent: 16-Mar-2022

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