View Reviews

Paper ID
340

Paper Title
An Improved Maximal Continuity Graph Solver for Non-repetitive Manipulator Coverage Path Planning

Reviewer #1

Questions

2. Briefly describe the paper and its contributions to robotics science and systems. You should attempt to re-express your paper's position so clearly, vividly, and fairly that the authors say, "Thanks, I wish I'd thought of putting it that way."
This paper contributes a graph solver for maximal continuity for non-repetitive manipulator coverage path planing. It offers a provable computational improvement to the problem of maximal continuity during non-repetitive object coverage using non-redundant manipulators. Baseline solutions rely on enumerating each point on the surface with multiple "colours" and model the problem as a painting of a graph of topological cells. Such approaches lead to computationally intractable solutions even for rather simple cases. To avoid the need to enumerate edges it exploits the topological invariance observed at colour intersections. It contributes a novel strategy to separate the graph into intersection-free sub-graphs and proves that the complexity is reduced by an exponential factor. The contribution is evaluated in simulation studies.

3. List any points of agreement (especially if they are not matters of general or widespread agreement).
The paper deals with a known problem of solutions on non-redundant manipulator based coverage path planning in tasks where continuity matters. I wouldn't say I have a comment on "agreeing" with a point of the paper as its nature is an analytical one and the result is either true or not (it is true). The authors let us understand how by first introducing the necessary background on intersection-free graphs, performing graph separation into strips, solving sub-graphs and aggregating the full solution they arrive to an algorithm with provably smaller (by a 2^N) factor computational cost to address the problem of maximal continuity for non-repetitive manipulator-based coverage path planning.

4. Mention what you have learned from this paper.
I enjoyed the paper due to its analytical presentation allowing to follow the process for graph separation into strips and leading to the resulting sub-graphs of the overall solution. The use of diagrams and the clear language allowed a complex derivation to be nicely presented.

6. Quality Score: This score reflects your assessment of the overall quality of the paper.
Excellent (among the most interesting papers you have read over the past year)

7. Impactfulness: This work is different enough from typical submissions to potentially have a major impact on a subset of the robotics community
Yes

8. Topic Novelty: This is a creative submission with ideas that initiate new direction and could define a new sub-area.
Yes

9. Appropriateness of presentation: The paper's length is appropriate given its content.
Yes

10. Explain your rating by discussing the strengths and weaknesses of the submission, contributions, and the potential impact of the paper. Include suggestions for improvement and publication alternatives, if appropriate. Be thorough. Be fair. Be courteous.
This is an excellent paper offering a detailed methodology with computational proof leading to much more efficient solutions on coverage path planning using manipulators in the context of applications where maximal continuity matters (e.g., painting/welding...). The nature of the work is analytical and thus the lack of extensive evaluation is not a concern. Essentially here evaluation is merely to demonstrate a result for which proof is provided.

11. Pandemic considerations: Social-distancing and other restrictions have likely been in force while the research reported in the manuscript was conducted. Has this imposed constraints on the work (e.g., feasibility of certain types of experiments) in away that you, as the reviewer, feel should be taken into consideration?
Not heavily affected type of work.

Reviewer #3

Questions

2. Briefly describe the paper and its contributions to robotics science and systems. You should attempt to re-express your paper's position so clearly, vividly, and fairly that the authors say, "Thanks, I wish I'd thought of putting it that way."
This paper address the problem of finding the paths for a non-redundant manipulator to cover a surface in a continuous way. One issue with the manipulator is that the mapping between joint-space and pose-space may lead to transitions between joint-space sets that require lifting the manipulator. This paper extends [12] which decomposed the problem into a topological graph by introducing an abstraction described as a topological intersection that separates the graph into intersection-free subgraphs. This allows to reducing the complexity of the solution by a factor of 2^N, where N is the number of edges in the topological graph. The complexity is formally proved and validated with experiments on a 6DOF UR5 robot for covering two different objects.

3. List any points of agreement (especially if they are not matters of general or widespread agreement).
The improvements achieved by the partitioning of the graph into initersection-free subgraphs is significant

4. Mention what you have learned from this paper.
By taking advantage of the structure of the sub-graphs the number of calculations is reduced

6. Quality Score: This score reflects your assessment of the overall quality of the paper.
Good (a paper that has its flaws but makes a good contribution)

7. Impactfulness: This work is different enough from typical submissions to potentially have a major impact on a subset of the robotics community
No

8. Topic Novelty: This is a creative submission with ideas that initiate new direction and could define a new sub-area.
No

9. Appropriateness of presentation: The paper's length is appropriate given its content.
Yes

10. Explain your rating by discussing the strengths and weaknesses of the submission, contributions, and the potential impact of the paper. Include suggestions for improvement and publication alternatives, if appropriate. Be thorough. Be fair. Be courteous.
Although the contribution does not extend the algorithm of the approach that it builds on [15], it does provide significant improvements on complexity with a well-developed complexity analysis and experimental evaluation.

Although the authors make a notorious effort in providing illustrations to help understand the proposed approach, I think that it would help to add in Fig. 1 details on the mapping between the task space and the surface for which this example is built.

Also, I recommend to be more concise throughout the paper.

Reviewer #4

Questions

2. Briefly describe the paper and its contributions to robotics science and systems. You should attempt to re-express your paper's position so clearly, vividly, and fairly that the authors say, "Thanks, I wish I'd thought of putting it that way."
The paper proposes a new approach to non-repetitive manipulator coverage path planning with the claim that complexity is reduced by a factor of 2^n. Simulation toy experiments are provided as proof of concept.

3. List any points of agreement (especially if they are not matters of general or widespread agreement).
The underlying problem addressed by the paper is of high relevance to multiple industrial robotics problems such as painting and deburring and should hence be of interest to the community.

4. Mention what you have learned from this paper.
The chosen approach via colorings of underlying cell-decompositions appears innovative and may have applications in a wider contexts beyond manipulation such coverage planning with multiple drones, etc.

6. Quality Score: This score reflects your assessment of the overall quality of the paper.
Fair (a paper that is on its way to making a good contribution but not there yet)

7. Impactfulness: This work is different enough from typical submissions to potentially have a major impact on a subset of the robotics community
Yes

8. Topic Novelty: This is a creative submission with ideas that initiate new direction and could define a new sub-area.
Yes

9. Appropriateness of presentation: The paper's length is appropriate given its content.

No

10. Explain your rating by discussing the strengths and weaknesses of the submission, contributions, and the potential impact of the paper. Include suggestions for improvement and publication alternatives, if appropriate. Be thorough. Be fair. Be courteous.
The results in this paper are I believe of interest to the community. I have to admit however that, for the non-expert on this sub-area of motion planning, I believe this paper is currently not easily readable and should be significantly revised with a focus on readability for non-experts and with attention to precision and clarity of claims and definitions.

It would help tremendously if the authors would make formal definitions in definition environments, for example to rigorously define "an intersection", as discussed in II A and to also formally put the underlying graph definition in a definition environment. The same holds for the section on defining Strips and to make a formal problem definition in the introduction. Similarly, for claims such as "proofs of complexity", a formal theorem + proof environment would clarify the exposition. Finally, the key algorithm proposed in this work could be condensed into a formal algorithm environment for clarity and precision. Browsing through the references, it seems that the cited paper [12] may provide much of the required background details, but given limited time and viewing the paper as self-contained, I am unfortunately not able to verify the correctness of the work as a result of uncertainties about the underlying constructions and definitions.

For example: Could the authors provide more background on the used cell-decompositions? How do they arise, what kind of cell decompositions are these? CW-complexes? Should cells be contractible? What properties are required of the cells? A short formal definition of how cells yield presumably space filling paths on each cell would clarify how this is related to path planning, and how this is achieved in the actual experiments. In the experimental section, it was also not clear to me how the cells and required numerical discretizations were obtained and no time/memory complexity analysis is provided to allow the reader to understand how close the proposed methods are to real-world use readiness. Adding these details would significantly improve the readability of the paper to the general RSS audience.

Other comments:
- the current draft should be shortened to 8 pages to conform to the submission guidelines. At the moment there is an overflow due to a citation.