English language and style

( ) Extensive editing of English language and style required  
( ) Moderate English changes required  
(x) English language and style are fine/minor spell check required  
( ) I don't feel qualified to judge about the English language and style

|  |
| --- |
|  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Yes | Can be improved | Must be improved | Not applicable |
| Does the introduction provide sufficient background and include all relevant references? | ( ) | ( ) | (x) | ( ) |
| Is the research design appropriate? | ( ) | ( ) | (x) | ( ) |
| Are the methods adequately described? | ( ) | (x) | ( ) | ( ) |
| Are the results clearly presented? | ( ) | (x) | ( ) | ( ) |
| Are the conclusions supported by the results? | ( ) | ( ) | (x) | ( ) |

Comments and Suggestions for Authors

The manuscript presents a method of fabrication of piezoresistive soft tactile sensor with pellet-based 3D-printing. Two configurations of the proposed sensor were fabricated where a simple grid layout configuration of the sensor was taken as the baseline to which “optimized morphology” of the sensor was compared against. In large, the paper is well-written with few grammatical errors. Some figure modifications could assist the understanding of readers. However, the core contribution of the manuscript is obscured by unclear experimental results and overlap with previous works. The following are my comments:

Major Comments:

* The introduction of the manuscript succinctly introduces the topic well.
* It is unclear to me why the authors are comparing the grid sensor morphology against the optimized sensor morphology both fabricated with the proposed method. As the authors noted, the previous work [27] extensively studied the joint entropy-based morphology optimization method for precisely this type of piezoresistive sensors. And this manuscript outlines its contribution to be addressing the previous work’s “drastic sim-to-real differences” rooted in “poor manual fabrication techniques” (lines 40-41). Then shouldn’t the comparison be between manually fabricated sensor and a supposedly improved 3D printed sensor of the same morphology?
* Why use a 6 DoF UR-5 robot when realistically the workspace the authors need for the experiment is just a 27mm x 27 mm x depth-of-indentation? I imagine the error of the UR-5 end-effector position is significant compared to the small size of the sensorized surface. Rather than dealing with the error propagation through the kinematic chain, wouldn’t it be more consistent to use some parallel mechanism? They are readily available and are affordable (e.g., cartesian robots/3D printers).
* The authors note that the print variability introduces significant enough errors to the sensor to merit training a single layer neural net/perceptrons just to address it (line 113). Doesn’t that undercut the motivation of this study?
* Some discrepancies exist with the data and the conclusion which should be addressed. As noted by the authors, loose connections produced some results inconsistent with the conclusions (line 229).
* If the authors are going to have to depend on “physical optimization” (line 236) where I assume the authors will build a bunch of different configurations and figure out the optimal morphology, what is the point of the simulations in this study?
* Perhaps I am just not finding this. But what is the depth of the indentation into the sensor during the experiments linked to Fig 4 and Fig 5? Or was it force controlled? Then what was the applied force? Since the response is assumed to be largely dependent on the strain of the fibers, this seems particularly relevant for the sensor characterization experiments.
* Capacitive response experiments (3.2) seem a bit out of place as is. I would suggest the authors weave in the results better. The presented results (Fig 5) are not very convincing that such “redundancy” of response data would improve performance.
* Without a baseline of manually fabricated sensors, it is difficult to interpret the results presented in Figures 7,8,10 in the context of the manuscript’s contribution. I see that the optimized configuration has lower errors overall but there are still (to me) significant underexplained differences between the simulation and real-world data.
* It is unclear to me in line 248, why the fact that minimum median error is lower with optimized morphology sensor than with the grid morphology sensor means the authors can develop sensors better suited to withstand certain wearing conditions better.
* The authors should include the specific method (and parameters if applicable) used for filtering the data. Was it just total variation denoising like from [27]?

Minor Comments:

* Some grammatical/diction errors are present throughout the manuscript (e.g., line 191 : “…simulator’s assumption of resistive dependence on local strain deformations is the effect…” should be “…simulator’s assumption that resistive dependence on local strain deformations is the effect”)
* Line 213: I believe “Figure 3” should actually be “Figure 4”
* Line 228: “does not appear” should be just “appear”
* In all figures with simulated vs measured results, I would include axes labels.
* Because this is a manuscript on a fabrication process, a figure of the fabrication steps could be very helpful. As is, I struggled a bit to imagine how the sensor is made.
* Paragraph starting at line 68: I think a table of the materials used in fabricating the sensor could be more useful than listing their properties in-paragraph.

Submission Date

28 February 2022

Date of this review

15 Mar 2022 05:10:32

English language and style

( ) Extensive editing of English language and style required  
( ) Moderate English changes required  
( ) English language and style are fine/minor spell check required  
(x) I don't feel qualified to judge about the English language and style

|  |
| --- |
|  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Yes | Can be improved | Must be improved | Not applicable |
| Does the introduction provide sufficient background and include all relevant references? | (x) | ( ) | ( ) | ( ) |
| Is the research design appropriate? | ( ) | ( ) | ( ) | (x) |
| Are the methods adequately described? | (x) | ( ) | ( ) | ( ) |
| Are the results clearly presented? | ( ) | (x) | ( ) | ( ) |
| Are the conclusions supported by the results? | ( ) | ( ) | (x) | ( ) |

Comments and Suggestions for Authors

In this paper, the authors present a 3d printable soft tactile skin. Two configurations of sensory networks are compared one is a common grid and one is optimized by genetic algorithms. The tactile skin is able to accurately find the touch position by using machine learning techniques. Moreover, the skin shows robustness in case one or more sensors are lost.

The topic is really interesting and the adopted approach seems very promising. However, in my opinion, there is not a sufficient level of novelty, with respect to the work of the same authors [27], to justify a new paper. The main differences are the fabrication techniques and some preliminary tests as capacitive sensors that do not give a sufficient level of scientific advancement.

More in detailed comments

* In the paper, a PLA probe of 5 mm has been used for indentation. Does the optimized grid work just for this specific probe dimension? If it is smaller or bigger which grid performs better? I think that such kind of analysis should be reported. If the desired application is tactile skin cannot rely on a specific probe dimension.
* Figure 4  shows the graph related to the indentation on the optimized grid that has a drop of resistance due to a short circuit with the closes resistive sensor. This cannot be considered a valid signal in my opinion. The dimensions of the resistive sensor should be decreased or the network should be partially modified to avoid this problem.
* In general, all the measurements of the sensors should be provided simultaneously and not just the single or two sensors considered because in this case there is the assumption that in the other channels there is no signal (they are zero) but, in a network like this, it is a big assumption. This is also more important for capacitive sensors. All the sensors should be measured at the same time because in capacitive sensors the noise is very high and in a not shielded network like this, it is probable that all the sensors reply to just the presence of the indenter. In fact, the signal (almost 0.1 pF) is very low, in the range of noise.
* One of the claims of the paper is that thanks to 3d printing techniques the reliability of the fabrication process improves and that should decrease the sim-to-real differences. However, the results obtained for the normal grid and optimized version are practically the same (the potential advantages of the optimized grid are nullified by the fabrication procedure).
* Also, I was wondering if the comparison between the normal grid and optimized one is “fair”. Actually, the optimized one has longer tracks that help in covering the skin. But what happens if the grid has a serpentine path?

Submission Date

28 February 2022

Date of this review

12 Mar 2022 18:12:42