Authors’ Response to the Reviewers

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Title: Towards The Internet of Smart Clothing: A Review on IoT Wearables and Garments for Creating Intelligent Connected E-Textiles
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The authors would like to thank the reviewer for his/her valuable comments, which have certainly helped us to improve the manuscript. Please find below our detailed responses to the comments. In order to ease the labour of the reviewers we have colored in red the major differences with the previous version of the article.

I. RESPONSE TO REVIEWER NO. 2

Comments and Suggestions for Authors

Overview

This manuscript provides a review of electronic textiles and wearable devices, with a focus on IoT enabled devices. The manuscript covers three core areas; the components that make up a smart garment, a review of current and future devices, and an analysis of future market opportunities. This work would be of interest to the growing wearables and e-textiles communities, and its holistic approach would make it particularly useful for people wanting an overview of the area. The overview on Market Opportunities at the start of section 4 is particular interesting. Unfortunately, there are issues with the manuscripts structure and content, which have been detailed below.

General comments

1. The manuscript is listed as an article but is really a review, as indicated by the title. This should be updated.

   Thank you for pointing such an issue out. We modified the template in order to indicate that the manuscript is a review.

2. The current narrative is somewhat unclear. This work is really a review and discussion of wearable computing with a focus on E-textiles, but at points the narrative is confusing as the review moves between wearable and E-textiles; this is very apparent in Section 3.1. Further, some areas are well described, while others are skimmed over. This may give the reader an unrepresentative view of the actual state of the field. While the paper states that it is a 'comprehensive analysis of the evolution of
smart wearables and garments, and their main characteristics and applications’, reading this manuscript as it is currently written, this is not comprehensive. The evolution of smart wearables and garments in particular is very short.

We do agree with the reviewer in his/her comments.

As it can be seen below in the different answers to the specific comments, we created a more focused version of the review in order to provide a comprehensive analysis.

Regarding Section 3.1, the aim of the section was to give a representative overview of the main commercial solutions without including an exhaustive study of all of them. Nonetheless, to complete the content, we added several references related to the evolution of smart wearables and garments.

3. This review would be a lot clearer if sections 2 and 3 were restructured. For example, both sections 2.4.2 and section 3 discuss sensors, which ultimately makes both sections incomplete. The authors may wish to consider re-writing these sections based on function.

Thank you for pointing out this issue. Sections 2 and 3 were structured with different aims in mind.

Section 2 briefly reviews the history of smart wearables and garments (providing additional literature for further research), their main types, the main end-user requirements and the basic components of a smart garment system.

Section 3 focuses on promising applications for IoT-enabled smart garments, either commercially or academically available.

Although some of the references could be representative for both sections, we did not consider to mix them in order to clearly emphasize their aim: one more focused on the proper development, while the other one is more focused on the potential of different applications.

To tackle this issue we clearly stated the aim of both sections: Section 2 (lines 228-229) and Section 3 (lines 472-474).

4. This review is very long and the authors should be more economic with language. There are areas of text without supporting citations that do not add a lot to the overall message, for example, I am not certain what lines 510 – 524 add to the narrative of this work. The introduction to this section could be reduced to a sentence (or simply start at line 525). Similarly, I think that the overall introduction could start on line 41. This would help with the structure of the piece, and make it easier for the reader.

Considering the specific comments 2-7, which affected lines 1-41 and 510-525, we decided to rewrote them taking into consideration the reviewer’s suggestions. Thus, we rewrote the introduction of the manuscript and the first paragraphs of section 3.2.1 in order to reduce the verbosity and, therefore, the length of the manuscript, adding some references to back the statements. In addition, we rewrote other paragraphs throughout the manuscript to decrease the mentioned verbosity level.
5. There are a number of times (some highlighted in the specific comments section) where a citation is needed to back-up statements.

   *We do agree with the reviewer. To tackle this issue we added multiple references to back-up different statements. Now the paper provides more than 260 references. Please see the specific comment section below for more details on such references.*

6. More references are needed in section ‘2.4.2. Sensing subsystem’. Many sensors are discussed without a reference and it is unclear to the reader what has been done or what could be done. At least one reference should be given to each of the sensor types mentioned. It would also be beneficial to draw the reader’s attention to comprehensive reviews into this area such as ‘Smart fabric sensors and e-textile technologies: a review’ and ‘Wearable electronics and smart textiles: a critical review’.

   *Corrected. As suggested, at least one reference has been cited for every sensor type. In addition, we would like to thank the reviewer for pointing at the first review, which has been added to Subsection 2.4.2. Regarding the second review suggested, it was already included in the previous version of the manuscript (as reference 101), but we decided to include it also in Subsection 2.4.2.*

Section ‘2.4.3. Actuation subsystem’ has a similar problem and requires more citations.

   *We agree with the reviewer. We added four additional references (one for each type of actuator).*

7. The language in section ‘2.4.4. Control subsystem’ needs to be revised. There are a number of grammatical errors. The way that this sub-section has been written makes the authors message unclear at points. I have included a couple of specific comments later in this review.

   *Corrected. The subsection was carefully revised in order to fix the mentioned typos and enhance its readability. The specific comments are also addressed below.*

8. There are minor grammatical errors throughout this manuscript. Some have been listed in the ‘Specific Comments’ section.

   *Thank you for the corrections. All the indicated errors have been corrected. In addition, we reviewed the whole manuscript and corrected several grammatical errors and typos.*

9. Section 2.4.7 should better discuss the battery technologies and better explain why they are not suitable for smart clothing. This would possibly be improved by including a summary table. This whole section is poorly cited and requires expansion and clarification. Line 359/360 states that ‘There are two main energy sources that may be harvested by smart garments’, which is not true. There is significant work in the literature where solar has been used (solar is discussed on line 363). The section does not discuss any of the significant body of work into wearable energy solutions (specifically energy storage solutions).
As suggested, Section 2.4.7 was modified to explain more clearly the main issues of the battery technologies used in smart clothing applications. Moreover, a new table (Table 3) that includes examples of wearable devices and the main characteristics of their batteries has been added. In order to avoid extending the length of the paper in excess, but since we think that the information of section 2.4.7 is actually relevant, we included a reference where the interested reader can find a detailed comparison of battery technologies.

Regarding Lines 359/360, the sentence actually referred to energy harvest from the human body, so it has been corrected to indicate such an aspect.

In relation to energy storage solutions, they are now detailed in Section 2.4.7.

10. Section 3.1 does not necessarily represent the ‘main commercial applications’ in this sector. I did not check every single reference but many of the citations that I checked are not for commercially available products (i.e. 120, 129), or do not represent a proper commercial application (i.e. 137 which is really an artistic piece). Beyond this, this list is missing a number of commercially available products in this sector. This shows a lack of understanding by the authors with regards to this field and recent and near-future commercial developments.

   We consider that the referred examples showed all the spectrum of available solutions, including prototypes developed in academia projects that are close to market or artistic pieces that can be sold. Nevertheless, in order to not confuse the reader, we decided to separate commercial available products of these prototypes. We also added a number of additionally commercially available products. Nonetheless, please note that the aim of the section was to give a representative overview of the main commercial solutions without including an exhaustive study of all the current solutions.

11. Further critical analysis of the applications discussed in section 3 is required.

   We do believe that the required analysis is already provided in other sections of the manuscript. Considering the nature of the available information, we consider that further critical analysis is not relevant, since the available commercial solutions are quite behind the solutions presented in the academic state-of-the-art. That is the reason why Section 3.1 just mentions the broad spectrum of solutions, taking into account that most of them either are not IoT-enabled or their specifications are not clearly stated. On the contrary, section 3.2 focuses on the applications, but mostly detailed advanced IoT solutions, giving the reference to the reader to deep into the inner workings of the specific application of interest.

Specific comments

1. Line 19/20: The keyword electronic textiles (as opposed to e-textiles on its own) would likely increase visibility.

   We agree with the reviewer. In order to complete the keywords we added ‘electronic textiles’.
2. Line 25: I do not necessarily agree with this statement. The concept of smart textiles encompasses textiles that can interact with the environment/user, so can include reactive inks. ‘Smart clothes can be created by embedding smart wearables into garments.’ would be more accurate.

   Corrected.

3. Line 27: These statements should be supported with references.

4. Line 28: These applications should be supported with references.

5. Line 31: Why is this a so-called wearable?

6. Line 33: The statement should be supported by a reference.

7. Line 34: This really needs to be expanded to clarify what you mean.

   Since the Introduction was rewritten, part of the comments do not apply. Nonetheless, such comments were considered in the writing.

8. Line 45: ‘...and smart textiles’ should have a reference.

   Thank you for pointing such an issue out. As suggested, we added an additional reference regarding advances on smart textiles in the mentioned position.

9. To my understanding there aren’t any examples of smart textiles coupled with 5G.

   We agree with the reviewer: since 5G is still being deployed worldwide, there are still not practical examples on its application to smart textiles. Nonetheless, the manuscript includes reference [12], which is a survey on 5G networks for Internet of things applications in order to enable device-to-device communications. This is now clarified in the manuscript and it is mentioned as an enhanced on the technology.

10. Line 48/49: ‘...have the potential to transform society.’ This needs to be strengthened. It is not really clear how this will happen from the text.

    The aforementioned sentence was supported by the analysis of a report of the European Commission ‘Smart Wearables: Reflection and Orientation Paper’ in 2016. Nevertheless, the report was only referenced in the next paragraph. As the reviewer recommends, such a reference it is now included to support also this paragraph.

    As the report explains, smart wearables and smart clothing when combined with other technologies (e.g., smart glasses, IoT, blockchain), have the potential impact to transform society due to their large-scale use in diverse applications and their transformative effects in many industries. In order to strengthen the statement, this clarification has been included in the corresponding paragraph.

11. Line 71: I would consider revising this title to be more descriptive.

    Thank you for indicating this issue. We have proposed an alternative and more descriptive title.
12. Line 72: This title should also be revised. This is really a brief overview of early wearable computing and the title should reflect this.

   We do agree again with the reviewer, so we rewrote the title.

13. Line 92: This does not make sense and must be re-worded.

   Corrected. The explanation about mediated reality was rewritten in order to explain such a concept more clearly.

14. Line 111: I do not think the use of the comma is correct.

   Corrected.

15. Line 135-137: Where has this distinction come from? I have never seen e-textiles separated into these categories, level of integration within the textile is a far more common method of distinction.

   The level of integration distinguishes between different levels of attachment of the sensors to clothing, e.g., separate, removable or embedded, and the corresponding form-factor. In the current version of the manuscript two new references are provided to indicate the source of the proposed categorization.

16. Line 137: This does not make sense and needs revising.

   The mentioned statement refers to Fig. 1, where, at the bottom, five levels of integration are distinguished, being the one on the right (smart clothing) the one that requires the highest level of integration. Since the statement referred strictly to Fig. 1, we consider that it was correct, but, in order to remove any ambiguity, we removed the last part of the sentence.

17. Line 138/139: I understand what you are trying to say, but this is not clearly communicated. This sentence needs to be revised/expanded.

   Corrected. We rewrote the statement to make it more clear.

18. Line 145: This should have a citation.

   We agree with the reviewer on his/her observation. Therefore, we added an additional reference.

19. Line 173: The placement of Figure 1 and 2 should be revised; currently they appear halfway through a list.

   Thank you for indicating this issue. We relocated both figures to position them closer where they are referenced.
20. Line 257: Optical fibres should also be included here.

Corrected. Optical fiber is now included in the potential display technologies.

21. Line 264/265: This is a major area of E-textile research and has led to a number of successful products. Historically this is the main area of E-textile development. This area should be expanded upon as the way this is currently written undersells the importance of this application to the reader.

We agree with the reviewer. Therefore, we rewrote the mentioned paragraph in order to reference explicitly heating and cooling actuators.

22. Line 272/273: The statement on FPGAs should be clarified.

Corrected. We rewrote the statement to make it more clear. The word `powerful` was related to the performance of the device. In addition, we emphasized the two main drawbacks when making use of FPGAs in wearable devices:

- FPGA design development is usually not as straightforward as microcontroller programming, since it often involves very precise resource (e.g., logic gates, embedded memory) interconnection and synchronization.
- FPGAs usually consume more power than other devices due to their need for powering the used logic continuously.

23. Line 276: The use of the term `extremely powerful` needs to be clarified.

Corrected. We rewrote the statement to make it more clear. The `extremely powerful` words were actually really ambiguous, so we now indicate that, since ASICs are designed explicitly for specific applications, they can perform tasks faster than the other mentioned embedded devices.

24. Line 316: This paragraph should really be expanded. The uses of RFID as a communication subsystem is extremely limited, yet you have covered this in detail and not really discussed communication technologies that would (potentially) allow connection to the internet or for off-device processing.

We agree with the reviewer on his/her observation. We have completed the paragraph to include additional details of other communication technologies. We also added a new table that shows a comparison on the main characteristics of the latest and most popular communications and identification technologies that could be used for smart clothing, indicating their frequency band, usual maximum range, data rate, power consumption and relevant features.
25. Line 338: I disagree with this statement, power is essential for electronic textiles. This does not necessarily need to be batteries (supercapacitors for example).

   We agree with the reviewer on his/her observation. We rewrote the statement and also include that there are other energy storage devices.

26. Line 351: You state that Li-ion batteries are bulky and add weight to the garment, but do not say the same for bulkier and heavier AA batteries a few lines earlier. You should clarify (or quantify) what you mean regarding the bulk and weight.

   We agree with the reviewer. We change the statement to indicate that Li-ion can be bulky. In addition, to illustrate the reader on the weight required by different types of batteries for regular wearable devices, we added a new table (Table 3).

27. Line 372/373: This is typically the case, but needs clarification and/or a citation (raw data can be transmitted to another device for processing).

   We clarify this issue in the first paragraph of Section 2.4.8 and added three additional reference to back the statements.


   Corrected. We rephased the content between the brackets, thus reducing the amount content included inside them.

29. Line 378/379: ‘The connection with the back-end is frequently performed via smartphones,' this requires a citation.

   As suggested, we included a new reference.

30. Line 385: Why untrusted?

   We modified the statement to make it clear that when using remote storage systems, the management usually depends on external companies. Therefore, integrity, availability and trustworthiness cannot be guarantee in every case and it is dependent on the behavior of third-parties.

31. Line 418: The wording of this sentence needs to be revised.

   Corrected. As suggested, we rewrote the statement to make it clearer.

32. Line 430/431: A citation is required.

   Corrected. The enumeration was not appropriate at such a point in the text, since numerous reference are provided in the subsequent subsections, so it was removed from the manuscript.
33. Line 432: The current placement of the figure breaks a sentence. It would be better if the figure was moved.

*Figure 4 has been repositioned to avoid breaking any sentence.*

34. Line 445: This statement should be supported by some figures/a reference.

*Corrected. We have included a reference to back the statement.*

35. Line 512: ECG and EEG should also be written out.

*Corrected.*

36. Lines 538-540: Additional discussion and citations are needed regarding the other vital signs that can be monitored. There is a wealth of literature out on these.

*We agree with the reviewer on his/her observation. We added additional details and 6 new references.*

37. Line 686-690: You need to explain why ‘consumers are likely to choose only one or a few selected brands over others to commit to and invest in as guardians of their personal bio-signals’ with supporting references to show that this is a likely market trend. Otherwise this is conjecture.

*The sentence was rewritten to mention a study that supports the fact that brand name is playing a crucial role in the decision to purchase wearable devices. We also added two references to back the statements.*

38. Line 711: This should read ‘be a force’.

*Corrected.*

39. Line 733: The cost needs to be stated to support this (I realise that this varies depending on application, but some indication should be given).

*We agree with the reviewer on his/her observation. We now provide the budget of the mentioned projects and added an additional reference.*

40. Line 779/780: This requires a citation.

*Corrected. We added a new reference to back the statement.*

41. Line 791: Why is durability a problem? This needs to be discussed.
The “durability” actually referred to “durability against deformation”. In order to clarify this issue, we included further justification and we added two additional references to back the statement.