Response to review of TCON-2008-0471, Ver. 1:

A Framework for Decentralised Feedback Connectivity Control
with Application to Sensor Networks

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18th March 2009

Maynooth, 18th March 2009

Dear Dr. Lamnabhi-Lagarrigue,

Many thanks for the recent review of our manuscript TCON-2008-0471, entitled *"A Framework for Decentralised Feedback Connectivity Control with Application to Sensor Networks"* that we have submitted for consideration for publication in the *International Journal of Control*.

In view of your recommendation we have revised the manuscript in accordance with the comments of the two reviewers.

Full details of all our changes are given on the following pages. We have reproduced all the reviews in italic font, with a small indentation. Our responses to the individual points are typeset in upright letters. To facilitate the work of the reviewers, we have highlighted noteworthy changes (that is changes other than fixing typos) with grey bars in the margin of the manuscript, and delimited the changes with little pencil symbols.

We believe that we have addressed all of the reviewers' remarks and questions, and are grateful for their very helpful comments. Furthermore, we have updated the references of the manuscript. We hope that the brief paper is now acceptable for publication in the *International Journal of Control*.

Yours sincerely,

Florian Knorn, Rade Stanojevic, Martin Corless, and Robert Shorten

Referee 1

This paper combines two results: the first one involves estimation of the algebraic connectivity λ_2 of a sensor network and the second one its indirect control by adjusting the communication radii of the sensors. The approach is novel and thus merits publication after the authors take the following remarks into account:

1) *While the references on connectivity control are adequate, there is a growing literature in robotics on connectivity maintenance the authors neglect- see Dimarogonas and Kyriakopoulos, Ji and Egerstedt, TRO papers for recent work on this approach*

The suggested references were added.

2) *introduction, last paragraph: I dont follow the comment "thus making assumptions on the distribution of the nodes in a probabilistic fashion makes no sense in our setting."*

We re-phrased this point to better explain it.

3) *what is the "averaging" matrix-this is nonstandard in consensus literature*

We added a comment where the term is fist used to point the reader to the notation section for its proper definition.

4) *please state $i \in N_i$ in (1)*

We added a "For each node $i = 1, \ldots, n$" in the sentence before the equation.

5) *is there a particular role of ϵ in the algorithm of fig.3?*

It is the threshold / precision based on which the estimates are either considered to be equal or not. We've added a comment in the third paragraph of Section 3.2 clarifying this.

6) *Propositions 3.1,3.2 seem to exclude the case $|\lambda_2| = |\lambda_j|$ for some $j > 2$. Is that the case? Cant this issue be resolved in a straightforward manner?*

We are now dealing with this issue in the second comment on page 8, just above Section 3.3.

7) Why doesnt case C converge in Fig. 4?

Maybe it was not clear enough that Figure 4 shows not several cases, but one instance (i.e. one network) on which the three estimators are compared. We have reformulated the paragraph above the comment in Section 3.3 to better describe this. Again, Figure 4 shows a situation where λ_2 is real-valued: It can be seen that the estimates of the two estimators for real-valued λ_2 (first two subplots) converge to the correct value, but the output of the estimator for complex-valued λ_2 (third subplot) does not converge to the correct value, since by design this latter estimator can only provide correct estimates for complex-valued λ_2.

8) Theorem 4.4 guarantees convergence to $\mathcal{R}$, however it does not guarantee that connectivity is maintained, i.e., that $|\lambda_2|$ stays stricly smaller than 1 for all times. I think that this is the case-that is, the set $|\lambda_2| < 1$ is invariant. Perhaps the authors should add a Lemma clarifying this important detail.

A comment has been added at the very end of Section 4.1.

9) Small notation issue in Appendix: what is y_i on the last line of page 25?

By the notational convenctions established in the paper, it is the ith element of the vector $\boldsymbol{y}$. We added a comment in item (2) of Appendix D to clarify this.

Referee 2

General remarks

Solid, interested paper providing decentralised algorithm for connectivity maintenance in a distributed sensor networks. It has to be underlined the potential of applicability of a given algorithm.

Paper structure

I appreciate very good paper structure. I appreciate also very good editorial standing of the paper. The idea, motivation and description of the way of meeting goals is given in very clear, cogent form.

Results

Results of the considerations given in this paper have been presented in the set of simulation examples. I think, that at least in summary section, the real target application fields should be pointed out.

1) Page 1, the title: Please consider to use uppercase N in Networks word.

Done.

2) Page 2, row 42: I would like to mention that power of radio transmitters are limited and must comply with appropriate national and international regulations and standards.

We fully agree that in an actual implementation one would have to take into account appropriate regulations and standards.

3) Page 2, row 49: It is a question what does it mean well connected graph?. I understand that authors enunciate further the self meaning of this "fuzzy" term. Please consider eventual explanation.

We define the term "connected" (in the mathematical / graph theoretical sense) later; to be more precise in this sentence, we added the word "densely".

4) Page 7, Proposition 3.2: Please explain or define or refer to, the term: strongly connected network. I think that it will enhance readability of the paper. Does strongly connected network assumption is not necessary for Proposition 3.1?

We now use the term "strongly connected" in both propositions, and it is defined at the beginning of the second paragraph of the Introduction.

5) *Page 7, Comment: I really agree with this comment. This comment is very important in practice because of the increased uncertainty of the estimate of the second largest eigenvalue of averaging matrix when running consensus algorithm over the network. Please mention, that given solution does not take into account limited accuracy and neglecting errors inherently connected with numerical calculations.*

We have added this to the end of the first comment on page 8.

6) *Page 9. row 32: Achievement of similar battery lifetimes is very important but please remember that battery power is not used exclusively for the radio transmission. It is used also by the sensors itself. This power is highly depended on the sensor construction. I think, that more practical is to achieve demanded connectivity by means of different measures rather then achieve of similar battery lifetime. Implementing the simple diagnostics of the predicted lifetime of batteries may help to overcome this problem.*

We rephrased the sentence slightly. Again, our point is that by forcing the use of a common radius the mathematical tractability is greatly simplified — but that this may also have its physical benefits.

7) *Comment: I suggest to consider eventually the problem: how arrange the sensors to fit demanded connectivity by ensuring optimal or near-optimal transmitting power.*

While this is an interesting problem, we focus in this paper on the case where the nodes are more or less randomly deployed over an area, and are immobile. In other words, the network has to "work" with a given fixed geographical set-up.