Responses to Reviewers

Report 1:
The paper deals with the design and simulation of a Synthetic nervous system for optic flow and directional selectivity computation, inspired by fruit fly visual system.

The authors show the network capability to select directionality of input stimuli.

The model is designed to detect both rising and falling brightness levels.

The network is based on non-spiking neurons, acting as leaky integrators, based on previous works.

This model is of extreme interest for the design of bio-inspired systems for rapid motion response to fast visual input features. Even if the model in not working with the same sensitivity in both (on and off) pathways, nevertheless the actual stage represents a very good achievement.

As regards the EMD, the authors take inspiration from the model Haag-Borst HR/BL three-arm EMD.

However, there is a much simpler model form the same authors, introduced in 1989 [1], from which several other papers were inspired to build artificial bio-inspired reaction systems, i.e. [2].

Some comparisons between the old and the new model would be conveniently done, which justify the model selection.

We have added in a discussion of the advantages of the three-arm model over the Hassenstein/Reichardt and Barlow/Levick models, citing the performance improvements found in Haag et. al. 2016.

Report 2:
Nourse et al designed a synthetic nervous system (SNS) capable of computing optic flow with directional sensitivity. They based their model on the Drosophila visual system, where motion circuit has been extensively studied, specially the ON pathway. One interesting aspect of the present work is that it considers recent connectomics data from Drosophila. The adaptations and simplifications of the Drosophila motion circuit has been done carefully based on the recent literature, but also having in mind future applications of this SNS in robotics, which gives a high relevance to their results.

*From the biological perspective, the authors have correctly adapted and simplified the motion circuit from Drosophila. **This is especially true, for the ON pathway. For the OFF pathway, there is a fairly recent paper that could be relevant, but is missing. Maybe the authors could have a look at it and check its relevance for the proposed SNS.***

We thank the reviewer for the suggested work. It is relevant in that it models the Off pathway, however we feel it is not fully up-to-date since it ignores the role of CT1 in suppression. We have added a citation to this work and made a note of the differences with our work.

Giving my expertises, I can not fully assess the computational and mathematical aspects of the paper

Report 3:
The manuscript by Nourse and colleagues presents a new model for direction selectivity based on our extensive knowledge of the Drosophila visual circuits. The authors develop a model of the directionally selective On- Off- pathways using a reduced number of non-spiking integrate and fire neurons with connectivity and filtering properties loosely based on biological connectivity and neuron properties.

The modeling seems solid, but the manuscript is at times dense and would benefit from additional schematics.

I have the following concerns.

Major Concerns

1.   There is no easy way of finding all parameters for the model. Individual parameters are scattered throughout the text, but I couldn't find a comprehensive list of all neuron parameters, connections etc. The github for the model is available but not structured in a way that I was able to reproduce the results.

We have added two tables at the end of the work, one giving the neural parameters and one giving the synaptic parameters. Additionally the github is currently disorganized, but will have more documentation and will be easier to navigate by the conference in July.

Minor Concerns

2.   Optimization of parameters is mentioned in the text, but no description of the optimization approach is given. I also think it would have been helpful to have a consolidated list/table of which parameters were identified analytically, and which from optimization.

Whenever we make use of optimization, we now explicitly list the method used with a citation. We have also added tables of the parameters, and included a field for whether they were found analytically or from optimization.

3.   The abstract and introduction motivate the novelty of this work by the new availability of the fly EM connectomes, but I couldn't find any description of how and which of these connectomes were analyzed and what data was used specifically.

We did not specifically use any raw connectomic data, our model is built using the connections described in previous work which used the raw data. We have clarified our text to make clear that we do not use any raw data by reusing citations in paragraph 4 of the introduction.

4.   Page 2, 2nd para, line 8: It would be helpful for a non-expert reader to add a definition of On and Off pathways here where you mention them the first time.

A brief explanation has been added describing the difference between these two pathways at this point in the manuscript.

5.   Figure 1: Why are the light blue neurons and the CT1 neuron bandpass filters (double circles) in the left schematic but not in the right?

Clarifying text has been added to the caption

6.   Figure 1: the open triangle outlines on the left are quite faint and hard to see. I suggest you increase the line thickness.

Line thickness increased

*7. Page 3, 1st para, line 4-5: "most neurons communicate when their state is between 0 and 1":
What does "most neurons" mean here, can you be more specific? Doesn't the synaptic transfer function
limit the communication to the range between 0 and 1 for all neurons?*

There is a single synaptic connection in the network which communicates in the range R to 2R.
Clarifying text has been added to the manuscript, and the full parameter tables have been added in the
appendix.

*8. Page 4, 3rd para, line 1: "in some instances it is desirable for a presynaptic neuron to
modulate..", Please specify either here which neurons these are or add that information to a table with
all parameters.*

Noted, clarifying text has been added and value tables have been added in the appendix.

*9. Page 4, section 2.2. I am confused about the description of the sub-network. A schematic (maybe
even including sample traces) would be helpful. In addition, unless I misunderstand something, you
label the neurons in this subnetwork as I, F, S, and O. You also use S and O in the main schematic
which is confusing. Please fix.*

The original notation was confusing, neuron names have been expanded for greater clarity to "I",
"Fast", "Slow", and "Out". A figure with the network topology and traces has been added.

*10. Page 5, sections 3.1 and 3.2: The mention of pixels seems to indicate the use of a visual analog
of these activation patterns being given to the input nodes. This is not how I understood what you are
doing. Please clarify.*

We have changed the text to omit any references to pixels.

*11. Page 5, section 3.1, line 2: You reference Fig 1. I suggest you add panel labels (A, B) to the
figure instead of referring to them as left and right and then refer to Fig. 1B in line 2 to be more
specific. I suggest doing the same for Fig 2, since you reference the panels separately in the text.*

Panels now labeled A and B

*12. Page 5, section 3.1, line 3: is "retina" the correct term here or would photoreceptor be more
accurate?*

Since we are referring to individual cells here, we have switched to use "photoreceptor".

*13. Page 5, section 3.2 para 2: is an inverted band-pass filter the same as a band-stop? Could you
elaborate?*

We see how this may be confusing, we reworded for clarity: "We apply a band-pass filter which
hyperpolarizes to stimuli of increasing brightness within each pathway..."

14.   Page 6, last sentence: Since the circuit is an EMD circuit, the intuitive understanding would be that an EMD neuron is any neuron in the circuit. When you refer to EMD neurons, I assume you don't mean all neurons in the EMD circuit? Are the EMD neurons you refer to here the neurons labeled On and Off? Please clarify in the text.

We have clarified references to the EMD neuron, referring instead to *On* and *Off*.

15.   Page 7, line 6: "cells in the medulla": I search in the text to identify which cells these are. It would be very helpful if you could indicate the anatomical structures in the schematic in Fig 1.

Anatomical structures have been added

16.   Page 7, line 8: I think this is the answer to my question about bandpass filters in Figure 1. However, this explanation is hard to understand without schematics or further elaboration.

See note 9

17.   Page 7, second to last line: please define the division factor.

We have added the symbol previously used for the division factor, for clarity

18.   Page 8, 1st para: "we are unaware of any studies which definitively reproduce the activity and mechanism of direction selectivity using these elements." It is unclear to me what you refer to here as "these elements". Are you aware of the following preprint? Lappalainen et al, bioRxiv 2023.03.11.532232; doi: https://doi.org/10.1101/2023.03.11.532232.

We have clarified the language, using "presynaptic neurons" instead of "elements". Additionally, we were not aware of this preprint as it was submitted shortly before our manuscript was submitted to the conference. This work is impressive, but does not use chemical reversal potentials in the synaptic modeling. We have added a citation to this work, and thank the reviewer for bringing it to our attention.

19.   Figure 3: It would be helpful to label the plots preferred and null and to label or give legends in the plots for the traces instead of describing them in the figure legend.

Labels and legends have been added.

20.   Figure 3: It is not intuitive to see that the left is enhanced over the right output. Could you show both on the same y-axis scale? Same for Figure 4.

Y-axis scales have been adjusted

21.   Page 10, section 4.3, line 5: I don't agree that these behaviors are similar. The magnitude is very different. It would also be helpful if you could compare this to biological behavior.

The intention we were trying to convey is adequately conveyed by the previous sentence, and the confusion is understandable. We have chosen to omit the offending sentence. We also described the biological behavior in *Drosophila*, and added an additional citation to Maisak et al. 2013.

22.   Page 11, section 4.4: How does this data compare to biological behavior?

We added an additional paragraph which describes the similarities and differences between our results and those found in *Drosophila*, with a citation to Maisak et al.