May 23, 2019

Response to the reviewers report

The following are your comments on our manuscript "A re-examination of the role of friction in the original Social Force Model".

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Referee (1)

The paper deals with the well known Helbing's social force model for simulating pedestrian dynamics. By means of some numerical simulations and comparisons with real data, the author improves the model unveiling, at the same time, the role of the friction coefficient. The author also shows that the role of the friction coefficient is basically the same of that of the relaxation time.

The paper is fine and I think it can be published, provided some corrections are made. More precisely, I think that the paper is not well organized and the message is difficult to follow. I strongly suggest to include Appendix A in the main text. Section 3 ("Numerical simulations") should be named somethink like "Setting and parameters". Section 4 ("Results"), which should be the core of the paper, is by far too long. Subsection 4.1 ("Hypotheses") is fine but does not contain "results". Subsection 4.2 contains numerical results, but they are not new.

Other comments:

1) Section 1: the author could add the reference to two papers which introduced the SF idea much before Helbing.

[A] S. Okazaki, A study of pedestrian movement in architectural space, Part 1: pedestrian movement by the application of magnetic model. Trans. A.I.J. 283, 111{119 (1979).

[B] K. Hirai, K. Tarui, A simulation of the behavior of a crowd in panic, Proceedings of the 1975 International

Conference on Cybernetics Society (1975), pp. 409-411.

2) End of page 6: "it is well known that the seminal version..." A reference should be added.

3) p.10: you cannot refer to `$\mathcal A$` and `\mathcal K$` like you do. The most important equations of Appendix A must be introduced here.

4) p.14: Fig.1 is not present.

5) Caption Fig.9: k is k_i or k_w?

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Response to Referee (1):

The following comments are outlined in the same order as appearing in the reviewer's report.

The reviewer suggests a reorganization of the manuscript.He (she) suggests to include Appendix A in the main text. We consider that this is a very useful advice. We included Appendix A and B in the main text (now Section 5.4 and 5.5 respectively). This modification helps the reader to better understand the core message of the paper.

The reviewer advices to modify the name of Section 3 ("Numerical Simulations"), we agree to rename Section 3 as "Setting and parameters"

The reviewer points that Section 4 ("Results") is too long and Subsection 4.1 ("Hypotheses") does not contain results. We moved the "Hypotheses" to a new Section previous to Results (now Section 4 is "Hypotheses" and Section 5 is "Results"). We also omitted Figs 4 and 5 to make the Section "Results" shorter.

Also, the reviewer made other comments.

1) The reviewer cites some research that introduced the SF idea much before Helbing *et al.*. We included the citations mentioned by the reviewer and the following comment in the revised manuscript (see the beginning of Section 1).

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In the last decades, many microscopic models for crowd dynamics have
been developed. One of the first models was developed by Hirai and
Tarui (1975) introducing the class of force based models [2]. These
models represent the interaction between pedestrians and their
environment using different kinds of forces inspired in physical systems.
For example, Okazaki (1979) modeled the movement the pedestrians
as the motion of a magnetized object within a magnetic field
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2) The reviewer points out that we have to include a reference at the end of page 6. We added the corresponding cite.

3) —

4) The reviewer indicates that Fig.1 is not present. We modified the text in order to clarified the fact that the Fig. 1 has a dashed circle that represents the measurement region corresponding to the fundamental diagram measurements.

5) In Fig. 9, κ means κ_i and also κ_w. We replaced κ by $\kappa_i = \kappa_w$ to make the caption more clear.

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Referee (2)

The paper studies the impact of the friction parameter in the original SFM.

At first I thought this is a work concerned with the calibration of a parameter in an old model for a special case: corridors. This sounds very specific and not so overwhelmingly interesting, right? However, I think this paper contains some nice ideas and results that are certainly interesting for the community if written and presented adequately. In my opinion the very best part of the paper comes in the last 2/3 of the manuscript. Only here, the paper starts to show interesting analysis and results, I would describe as original. I think the authors would be better off focusing more on the content in Appendix A and B. This nice normalization, is good. from there work with Eq. (A.3) and go on with the clustering analysis. The analysis shown in Fig. 6 is also interesting. Here, I wish the authors could shed more light on the famous boundary effects, so controversially discussed in the literature.

Here are some specific comments to the text:

1) Reading the introduction, I believe the authors know very good the works done by Helbing and some of his co-authors, especially Johansson. Most of the references in the text are citing these two (Ref. 2 most of all). I believe, it would be good to broaden a bit the literature review in the introduction to more recent works as well. At last, during the last 10 years some positive development in the community could be observed, right?

2) I also suggest to reduce the obvious enthusiasm of the authors and dispense with the use of superlatives like "a wonderful summary" or "a seminal work" (repeated many times). By the way, Ref. 16 is from 2007. A more recent review of empirical data can be found here doi : 10.1007/978 - 3 - 642 - 27737 - 5_706 - 1" Empirical Results of Pedestrian and Evacuation Dynamics"

3) The very first paragraph in the paper is not quite accurate in my opinion. The force social force model ever presented was

published in K. Hirai and K.Tarui in 1975 (a simulation of the behavior of a crowd in panic, Proc. of the 1975 International Conference on Cybernetics and Society. (1975) 409-411). The model was not called SFM, but it is a force-model that "nicely bridges the socio-psychology with Newtonian dynamics".

4) It is not clear to me why the SFM explains why the faster-is-slower effect happens. It can be produces, yes, but it does not explain why. Please clarify or reformulate.

5) In general the authors write "Helbing and co-workers". I suggest to use the more formal et al. This is also more necessary in the references. There sometimes the authors use all names of the authors and sometimes only the first author followed by et al. Please also check some errors in some names (K\"oster, L\"ohner, . . .)

6) Equations are missing punctuation.

7) Section 3: Why is the length of the corridor L=28m while the width is w=40m. This sounds strange and I'm not sure if it is necessary to have some big values for w.

8) Section 3: Why are the details about the implementation (C++, LAMMPS) necessary? I think unless the authors are intending to open-source their code (which would be nice by the way) there is no need to mention these details. Also the authors mention a LAMMPS built in function calculating the clusters. What is this function?

9) Section 4: Here the authors cite a lot of other works, especially from 2 and 36, but they do not give their own opinion, in regard of the new findings. Again just a reminder Ref 2 is 10 years old. For new findings see Loehner PED 2016 in Hefei.

10) Page 10: vd is the desired speed not the "anxiety level".

11) Page 14: "In our case, pedestrians near the walls are the ones with the lower velocity". Is this a know empirical fact? Why is it so? Maybe the authors could explain more this phenomenon.

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12) I think Fig. 4 and 5 can be safely removed and just replaced
with Fig. 6. The normalisation here is nice.

13) The interesting phenomenon the authors show in page 23 was not
well analysed and explained. Why is it for high k pedestrians
stick together more? Intuitively I would think that high k means
high repulsive forces which means that pedestrians stay away
from each other not other way around.

14) In Appendix A the two Parameters in Eq. A.3 are not discussed.
Instead the focus is still on tau and k. How is this good? Why do
you normalize the model, come up with two parameters only then
to continue discussing the parameters in the un-normalized
model?

To summarize, I think this paper can be published. However,
some heavy restructuring and deeper analysis on the points of
interests may be necessary.

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Response to referee (2):

The following comments are outlined in the same order as appearing in the reviewer's report.

1) —

2) The reviewer suggests to dispense the use of sentences like "a wonderful summary" or a "seminal work". In order to avoid these expressions, we replaced them by more appropriate words throughout the manuscript.

On the other side, we acknowledged the citation introduced by the reviewer and we included it in the revised manuscript.

3) The reviewer points out that the first paragraph of the manuscript is not quite accurate. Also, indicates that the Social Force model was introduced

much before Helbing *et al.*.

Section 1.0 (Introduction) has been improved taking into account his (her) comments and, also, the reviewer's `#1` ones (see above).

4)The reviewer points out that the SFM reproduces the faster-is-slower effect, but the model does not explain why the faster-is-slower occurs. We agree with the reviewer and reformulated the text in order to fulfill this statement.

5) The reviewer suggests to change some sentences, like "co-workers" by the more formal *et al.*.

We acknowledge this issue and made the corresponding changes in the revised manuscript.

We also corrected the names of the following authors: Köster and Löner

6) The reviewer noticed that equations are missing punctuation. We added the appropriate punctuation when needed.

7) The reviewer wants to know the reasons for the analyzed corridor dimensions.

The length (28 m) was chosen according to the dimensions of the entrance to the Jamaraat Bridge. The width was varied upto 40 m just to check out if the velocity profile had a qualitative difference with the velocity profile corresponding to narrower corridors (say 12 m). We discovered that regardless the width of the corridor, the behavior of the scaled velocity profile remains the same.

8) The reviewer asks why we mentioned the details of the implementation despite we do not open-source our code.

In order to allow the reader a better inside of the simulation process, we consider important to point out the details about the implementation. The code is not open-source yet. Before open-source the code we are working in documentation and clean up to make it easier to understand by new users and maintain.

Furthermore, the reviewer wants to know about the LAMMPS built in function for computing the clusters.

We included in Subsection *Simulation software* the name of the LAMMPS built in function and we provided a brief explanation of how this function works.

9) —

10) We acknowledge this issue and made the corresponding change in the manuscript.

11) Pedestrians near the walls are the ones with lower velocity because the pedestrians which are closest to the wall are the ones who dissipate more energy due to the friction force (exerted by the wall). We do not know if this behavior is reported in empirical measurements.

This phenomenon resembles a viscous fluid velocity profile (where the lowest velocity of the fluid is located close to the walls while the highest velocity is in the middle of the pipe).

12) The reviewer suggests to remove Fig. 4 and 5 and just replaced with Fig. 6. We consider that this is a very good advice and we removed Fig. 4 and Fig. 5.

13) The reviewer want to know why as κ-value increases, the more pedestrian's stick together.

We are glad to explain that κ is the coefficient of the friction force and, therefore, is not related with the repulsive force $\mathbf{f}_s$. Thus, as κ increases, more pedestrians stick together due the nature of the frictional force. Also, we want to remark that the friction force is tangential to the center of mass between two pedestrians, while the social force is normal to it.

14) The reviewer claims that the two parameters in Eq. A.3 are not discussed. We acknowledged this issue and added a brief interpretation of the two parameters when introduced.

The reviewr asks why we normalize the model and then continue discussing the parameters in the un-normalized model.

We prefer to continue discussing the parameters in the un-normalized model to make it more understandable for readers that are used to the un-normalized parameters of the SFM. We are planning to further investigate this normalized parameter and write a new paper focusing on the normalized equation of motion and the role of the different parameters of the SFM. This manuscript is a first attempt to study the model in the framework of the reduced in the units equation of motion. We also pretend to encourage the community to study the SFM following this approach.

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Referee (3)

The authors discussed the role of friction in SFM. The topic is interesting and worthy studying. However, there are issues that should be addressed before processing to a possible publication of this work.

1. Nonstandard reference issues:

(1) Numerical order. For instance, \[10, 12, 8]" (Introduction, page 5, paragraph 1).
(2) The format of References is inconsistent.

2. The format of unit is nonstandard. For instance, \Pm- 2 " (Fig.2) and \p/m 2" (Fig. 3).

3. Numerical simulations, page 8, paragraph 3: The desired velocity for each pedestrian was 1 m/s. Whether the desired velocity has an effect on the result?

4. Clusters, page 22, paragraph 2: In an enhanced friction scenario the individuals find it harder to detach from each other. Then why are possibilities of pedestrian belong to a small cluster and giant cluster almost equal? Why does a bimodal distribution occur in Figs. 9(d)-(f)?

5. Why does not the velocity profile report any relevant difference as the corridor widens, while the fundamental diagram does?

6. Numerical simulations, page 7, last paragraph: Initially, the individuals were randomly distributed along the corridor, and the corridor with periodic boundary conditions. Whether the initial distribute and boundary conditions may have an effect on simulations?

7. English writing should be improved.

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Response to referee (3):

The following comments are outlined in the same order as appearing in the reviewer's report.

1-2) We acknowledge these issues and made the corresponding change in the manuscript.

3) The reviewer asks whether the desired velocity has an effect on the result.

The answer to that question is yes. If the desired velocity is much greater than 1 m/s, the flow vs density relation is a monotonic increasing function. If the desired velocity is less than 1 m/s, the results are very similar to 1 m/s. We decided to use 1 m/s because is roughly the average velocity of a moving pedestrian under normal conditions.

4) The reviewer asks why are the possibilities of pedestrians belong to a small cluster and giant cluster almost equal.

This interesting phenomena occurs because while most of the pedestrians belong to the giant component, some pedestrians remain isolated (”caged” inside the giant component without being in contact with other pedestrians). This produces the bimodal distribution in Figs. 9 (d)-(f)

5) The reviewer asks why does not the velocity profile report any relevant difference as the corridor widens, while the fundamental diagram does.

This happens because the fundamental diagram is strongly dependent on the velocity attain by pedestrians. If the corridor widens, the pedestrians in the middle of the corridor (where the fundamental diagram is measured) reach higher velocities.

On the other hand, the qualitative behavior of the velocity profile is the same regardless the size of the corridor (parabolic shape). This does not contradict the fact that the wider the corridor, the higher the maximum velocity reached. The shape of the velocity profile only depends on the boundary conditions in the y-coordinate (fixed walls) that leads to a parabolic velocity profile.

We modified the section that shows the velocity profile, in this new version we only show the scaled velocity profile.

6) The reviewer asks whether the initial distribution of pedestrians and boundary conditions may have an effect on the simulations.

We checked different initial conditions and saw no significant results. We also tested a situation with a corridor 10 times larger (L = 280 m instead of L = 28 m) to reduce the effect of the boundary conditions. We neither noticed any significant change in the result.

7) The reviewer suggests to improve the English writing. We agree with the reviewer and modified some sentences to satisfy this important requirement.

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Your consideration of this revised manuscript for publication in *Safety Science* is greatly appreciated. Please find attached the new version.

Sincerely