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RE: External examiner review of Doctoral Dissertation by Jana Vacková called "Modification and Calibration of Pedestrian Models Using Microscopic Analysis of Crowd Dynamics"

I am pleased to provide my external reviewer opinion concerning the doctoral dissertation by Jana Vacková, performed under the supervision of Prof Milan Krbálek and Marek Bukácek .

My expert opinion report is made of four sections, including a background, the appraisal of Jana Vacková doctoral dissertation, future research based on the dissertation and a set of concluding remarks.

Background

Pedestrian dynamics is a timely and relevant domain in the context of urban planning, engineering design and safety engineering. The premise in the dissertation is that – despite its importance - calibration is often not fully assessed when presenting pedestrian modelling tools. This is true and the doctoral dissertation sheds light on the topic. In addition, the review and identification of widely applicable methodologies to measure pedestrian densities is an important work for the pedestrian dynamics field. This is a known and important issue, since current methods (e.g. Voronoi diagrams, minimum distance estimates) present indeed a set of limitations. This includes for instance the trimming required to the reference areas in presence of walls or obstacles and in more general term, the choice of reference area for pedestrian density estimations. The choice of a static (e.g. detector approach) or dynamic area is also currently under debate in the pedestrian dynamics community.

Appraisal of Doctoral Dissertation

The doctoral dissertation explains in detail the key concepts and approaches related to estimation of pedestrian densities, demonstrating the candidate has a clear understanding of the subject matter. English language is according to scientific standards, although in some instances, especially in the introductory parts of each section, phrasing could have been simplified since the text requires pre-knowledge of pedestrian dynamics concepts to be fully grasped. This could be considered a reasonable decision given the reader may be expected to have a ground knowledge in the domain of the PhD dissertation. The experimental and modelling work has been performed in a rigorous manner, in accordance with the scientific standards of the pedestrian and evacuation dynamics community. Ethical aspects associated with the conduction of pedestrian experiments could have been discussed in more detail. A very

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interesting and well-written part of the dissertation relates to the assumptions related to pedestrian surroundings and their impact in estimating pedestrian density. The model developed in the dissertation introduces a set of novel ideas regarding the way to treat pedestrian modelling, i.e., looking at physical size and social size. The section on calibration is well written and adopts well-known statistical concepts in the context of calibration. The choice of quantities in the calibration section is very important for usability of the approach, and this could have been based on existing guidelines for Verification and Validation of pedestrian models.

Future research based on the dissertation

The doctoral dissertation lays the ground for a set of future studies in the domain of density estimations and pedestrian modelling. For example, future concepts that could be explored based on this thesis work include a comprehensive understanding of density estimations in 3D spaces. The thesis addresses mostly a two-dimensional space, while it would be interesting to know how to deal with densities in three-dimensional elements (e.g. staircases). In addition, the experimental tests are conducted mostly with students, so in the future it would be interesting to investigate explicitly case studies related to other types of populations, e.g. people with different types of disabilities (e.g. blind, wheelchair users, etc.), which may adopt very different pedestrian navigation methods. This could then be reflected in modelling (the author mentions this herself in the dissertation). The dissertation represents a valuable first step towards an improved estimation of pedestrian densities primarily for homogenous adult and healthy populations. Nevertheless, the new ideas related to both modelling, density estimations and local comfort may be a starting point for a novel perspective to address the study of heterogenous populations. This is a pressing issue in the pedestrian dynamics field since most models today are primarily designed for "standard" adult populations. Other aspects which would be worth to explore further is the evaluation of density estimations in relation to convergence methods over probabilistic repeated runs. This is another known gap in the pedestrian dynamics field which this thesis could help solve. Further verification and validation of the new pedestrian model could be performed considering existing standardized testing, especially to evaluate its usability in a wider range of applications and scenarios.

Concluding remarks

The PhD thesis is overall well written and of publishable standards. The background on the topic is well explained, and it seems targeted to an audience of readers interested in the field of pedestrian dynamics or applied mathematics. An alternative approach could have been to provide a more general discussion on the implications of the work conducted for engineering applications. Minor language improvements could have benefitted the manuscript, and some minor editorial issues could be identified (e.g. typos in page 55 with Figure number missing,

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unwanted question marks at page 44 or 106, etc.) although those could be considered negligible. The thesis presents several novel concepts which definitely highlights the value of the work performed. Two of the scientific papers by the author are published in reputable peer-reviewed journals with impact factor, further demonstrating the quality of the work performed.

My overall final recommendation is that the doctoral dissertation complies with international scientific standards in the field and I therefore strongly recommend it for public defence and publication.

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