Review of dissertation thesis

Author of the Thesis: **Tomas Bravenec**

Title of the Thesis: **Exploiting Wireless Communications for Localization: Beyond Fingerprinting**

Reviewer of the Thesis: **Adriano Moreira, Escola de Engenharia, Universidade do Minho (Portugal)**

Theoretical framework and bibliography:

This thesis described research work developed within the broad area of indoor positioning.

The title of this thesis and, to some extent the abstract, suggests that this work is about localization solutions based on wireless (meaning radio) communications.

On the other hand, the research gaps identified in section 1.3 point into two specific topics: one related to privacy and another related to the computational burden associated to some algorithms, implicitly related to indoor localization.

The summary of the main contributions, described in section 5.2, confirm that this work focused into the two main topics identified above, and that are quite different in terms of research area.

Although the candidate reveals to have acquired considerable expertise into these two areas, focusing in just one of them would have the potential to give the student the opportunity to go deeper into the technical details and, eventually, achieve more significant results.

Regarding the topic of privacy, where the work addresses the risk of a person be detected and tracked by sniffing some management frames transmitted by personal Wi-Fi devices, the student shows to have acquired relevant knowledge on the technical details of Wi-Fi networks and explains how some characteristics of these networks can be exploited and put privacy at risk. This is complemented with some experiments that prove how easy that can be actually done. On the other hand, the work does not propose specific measures that could be implemented in future versions of Wi-Fi to mitigate these weaknesses.

Regarding the topic of computational requirements, the context and theoretical framework is somehow confusing. The student provides a good introduction to machine learning in section 2.3, showing that fundamental background knowledge has been acquired. On the other hand, there is some confusion between computational complexity and computational burden, and there is no clear motivation for the connection between machine learning and indoor localization (more on that below).

The list of bibliography is comprehensive and relevant.

Novelty of the topic:

The problem of privacy raised by the widespread and ubiquitous use of wearable and personal devices has been extensively addressed by the research community and, despite the many advances,

is still a relevant topic. Therefore, the privacy-related topic addressed in this thesis is welcome, especially as it considers the context of indoor localization and tracking (and presence detection).

Likewise, the study related to the problem of running data-intensive algorithms in computational devices with limited resources is also still relevant. In this context, the idea of using interpolation for reducing the computational burden associated to position estimation in Wi-Fi fingerprinting-based indoor positioning is promising, while not new. The described work is more focused on evaluating a particular approach rather than on proposing a new approach. On the other, the part related to minimize the computational requirements associated to running CNNs, by using lower precision representations of the models is, somehow, disconnected from the main area of indoor localization. The student does not provide any reasoning as why he made the experiments using an image dataset instead of using datasets related to indoor localization.

Methodology:

The two main topics of this work are addressed using similar approaches.

For the privacy-related topic, the student starts with a study of the technical specifications of Wi-Fi networks, with emphasis on the details of Probe Requests and, based on that knowledge, designed a set of experiments to collect data that were later analysed to reveal the weaknesses in terms of privacy. The experiments are well documented and supported by open-source software and datasets that were both shared with the scientific community to improve the reproducibility of the work. The obtained results are conclusive and well explained.

Regarding the problem of the computational burden, there are two parts. The one related to minimize the memory requirements to run CNNs is addressed by performing a set of experiments using an image dataset and comparing the time and accuracy results. Here, the experiments could have been extended by also looking into the training stage using limited precision, and comparing the results with the cases where the training is done using full precision and the classification is done using limited precision. The part related to the effort of manually creating radio maps and also using those radio maps to estimate a position is more confusing. The better results, in estimating positions, are obtained by reducing the radio map to a single fingerprint per reference point, which is rather obvious. The experiments related to use a method to interpolate the radio map are not very conclusive. In this part, there are other previous works that were not referred to.

Relevance of the results:

There are several relevant results resulting from this work.

The published open-source software and the published open-access datasets are significant contributions to the scientific community, not only because they contribute to improve the reproducibility of the work, but also because they can be used by other researchers in further experiments. The open-source software can even be used as a base for the development of commercial products to detect the presence of people in spaces.

The results related to the privacy problems is useful as it creates awareness about the risks of presence detection and tracking. What is missing here is a proposal to minimize these risks by introducing new mechanisms in Wi-Fi networks.

The results obtained by experimenting with different levels of precision in the representation of models in CNNs are questionable. Firstly, there is no clear statement on the novelty of these results. Secondly, the obtained results are not necessarily generalizable to other applications other than

image classification. Therefore, no conclusion can be drawn about its application to the area of indoor localization.

Regarding the problem of the radio maps, the obtained results confirm the trends reported by other researchers, even though they are not directly compared to the later.

Evaluation:

The evaluation of the described work is done through experiments of several types, which are themselves part of the research methodology. In some cases, the experiments include collection of data in real-work settings and the corresponding data analysis. In other cases, the experiments are based on the analysis of open-access data using available software libraries. In all cases, the experiments are well described and the obtained results are technically sound and credible.

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Assinado por: **ADRIANO JORGE CARDOSO MOREIRA**
Num. de Identificação: 07425168
Data: 2023.11.22 12:09:09 +0000

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