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: **Sergi Trilles Oliver, Universitat Jaume I Spain, Institute of New Imaging Technologies**

Theoretical framework and bibliography:

The thesis is built upon a solid theoretical framework reflecting a thoughtful and well-considered approach to the chosen topic. The PhD candidate has used many relevant bibliographic citations, indicating a comprehensive engagement with existing literature. The author has effectively integrated these citations to support the key arguments, providing a solid foundation for the research and ensuring a scholarly context for the study.

Novelty of the topic:

The thesis focuses on enhancing indoor positioning systems, a cutting-edge and innovative topic. It provides valuable insights into non-cooperative user tracking, presence detection, and occupancy estimation. The research explores the optimization of machine learning algorithms and indoor positioning algorithms utilizing RSSI fingerprinting. Throughout the thesis, the PhD candidate provides datasets of probe requests, analysis scripts, and packet sniffer firmware for ESP32 microcontroller for future research.

Methodology:

The thesis demonstrates a methodologically sound and rigorous research methodology, with a systematic design and execution that considers research objectives carefully. Appropriate data collection techniques, machine learning analyses, and reproducible methods ensure reliable and valid results.

Relevance of the results:

The PhD candidate has made valuable contributions to scholarship, as demonstrated by the impressive results achieved. The author has published six articles, one of which is in a reputable journal. Additionally, the author has produced and shared software and datasets, promoting reproducibility and contributing to the scientific community.

Evaluation:

This thesis delves into the field of Location-based Services (LBS), with a particular focus on privacy concerns related to Indoor Positioning Systems (IPS) that use Wi-Fi technology. The author examines non-cooperative user tracking by analyzing unencrypted Wi-Fi management frames, specifically Probe Requests. The research demonstrates how these frames potentially threaten location privacy and proposes an algorithm that uses Received Signal Strength Indicator (RSSI) measurements to estimate room occupancy.

Additionally, the thesis optimises computational requirements for machine learning and positioning algorithms. This includes reducing memory requirements for neural networks by using half-precision weights with minimal accuracy loss. The optimization also explores interpolation techniques that enhance fingerprinting methods in IPS. The research reveals that a less dense grid can improve accuracy and reduce inference time.

Throughout the thesis, the PhD candidate provides datasets of probe requests, analysis scripts, and packet sniffer firmware for ESP32 microcontroller for future research. Overall, this work contributes insights into non-cooperative user tracking, presence detection, occupancy estimation, and optimizations of machine learning and indoor positioning algorithms using RSSI fingerprinting.

The following comments and suggestions encapsulate the expertise and feedback of this reviewer, aiming to enhance this thesis dissertation's overall coherence, depth, and academic rigour. The comments are divided into the document chapters. At the same time, a PDF document with notes is provided. These notes include the following points and some minor corrections. PDF link: http://bit.ly/3MIX9JQ

Abstract.

-The summary should begin by outlining the main objectives of the research work. The concluding statement, “The thesis provides insight into non-cooperative tracking of users, presence detection and occupancy estimation, as well as into optimizations of machine learning algorithms and indoor positioning algorithms employing RSSI fingerprinting”, effectively encapsulates these goals.

-It is not customary to define acronyms in the abstract.

Introduction.

-Regarding the sentence: "In this case, the central question is privacy in indoor positioning and localization…". I believe that the thesis has two main objectives. Stating that the primary goal is privacy is not entirely accurate, and the sentence needs to be rephrased to make it clearer.

-Privacy keyword should be mentioned in the RO1 (text in bold).

-The list of publications is in the last chapter (Chapter 5). The “Thesis Outline” should be revised.

Methodology.

-All acronyms and abbreviations should appear in their complete form on their first occurrence. For example, Bluetooth Low Energy (BLE), Access Points (APs), and Machine Learning (ML). Refer to the attached PDF for more acronyms.

-It is often preferable to use words to express low numerical values. Refer to the attached PDF.

-Throughout the document, some statements require citations to justify them. For example: “For the research into indoor positioning and privacy issues, the WLAN and PAN technologies are most interesting.”. Refer to the attached PDF for more examples.

-Section 2.3 lists the advantages and disadvantages of each technique except Artificial Neural Networks. Advantages for Artificial Neural Networks should be added.

-All the techniques listed in this chapter are too general. I recommend only including the most relevant and recent ones related to the techniques used in the thesis.

-It is important to specify which version of the ESP32 MCU was used for experimentation and which versions are compatible with developed sketches. These details should be added.

-To enhance the understanding of Table 2.5, a figure showing the different RPs should be included or referenced if it already exists in the document.

Exploiting Wi-Fi Management Frames for Presence Detection.

-It would be helpful if definitions for A and B could accompany Equation 3.1. This would improve clarity and understanding. I assume that they refer to devices A and B.

-On page 79, it is mentioned that a threshold of ">0.5" is utilised. However, it is unclear how this threshold was determined, whether through experiments or from previously published work.

-In the same way, line 17 of Algorithm 3 requires clarification on how the threshold of "5" was determined.

-It seems that the algorithms run on the MCU, but the thresholds are defined offline. Can you please clarify if the thresholds are obtained during the data preparation step? This inconsistency must be resolved because if the thresholds are coded a posteriori, then not all the algorithms run on the MCU.

-Page 93 mentions various thresholds ("−56dBm, −63dBm, and −66dBm"). It is unclear how these thresholds are obtained, whether through experimental means or referencing prior work.

-On page 94, an estimation of the number of people is proposed. Please clarify if you suppose that each person has only one device. Currently, people usually carry more than two devices.

Balancing Accuracy and Complexity.

-Section 4.1.1 should include references for technologies such as TensorFlow Lite.

-The correct term is "TensorFlow Lite," not "Tensorflow light."

-Section 4.1.2 is unnecessarily repetitive with the Introduction chapter, particularly Section 1.1.2. One of the sections should be reduced.

-The Introduction chapter only briefly mentions Channel State Information (CSI), a topic requiring a more detailed description (such as RSSI).

-The average frame rate displayed in Table 4.2 is unclear how it was calculated. Please provide clarification on the number of runs and conditions used.

-The accuracy of the model created with MobileNet V2 significantly decreased. Could you please identify the reasons and differences with other datasets?

-Section 4.2, which discusses the use of ML optimization for lowering data precision, appears to be somewhat disconnected from the overall focus of the thesis on Indoor Positioning Systems (IPS). One potential solution could have been incorporating the findings into the models presented in Section 4.3, although I understand that different data types were used. I am interested in exploring the potential application of Convolutional Neural Networks (CNN) for IPS using Radio Maps as images. Could this be feasible? This could be a possible direction for future research (and an item in the future work subsection). See this work: Chen, H., Wang, B., Pei, Y., & Zhang, L. (2020, November). A WiFi indoor localization method based on dilated CNN and support vector regression. In 2020 Chinese Automation Congress (CAC) (pp. 165-170). IEEE.

-It would be helpful to understand the reasoning behind using five sniffers, with one placed in the centre of the room and the remaining four in each corner of the office. Referring to previous studies that have tested different configurations to support this decision might be beneficial.

-It is useful to present execution times standardized for relative comparisons between various model configurations. However, in Table 4.6, global times are mentioned. If you provide overall times, you should indicate more details regarding the conditions under which these timings were recorded. It should be clearly stated whether the mentioned times are averages. If so, the statistics (standard deviation, minimum, maximum, etc.), along with the number of executions, should be included.

-Concerns were raised regarding Table 4.7 due to the omission of grid=2 in the precision (positioning error), which is notable, especially considering that the latter configuration had the best execution time.

-Upon reviewing all the experiments, it is not clear whether the models developed in the study can operate on battery-powered devices, as supposed in the document: "This approach drastically reduced both memory and computational requirements, which is and always will be important in order to have more processing time available for other tasks or save battery in battery-powered devices by needing less time and energy for computing." It is a drawback that the experimentation was not conducted on devices in a real-world environment, as in Section 4.2, and only used MCUs for data collection. This point could be left open for future research.

Conclusions.

-Section 5.1 needs to be more specific by listing outcomes from previous chapters.

-The weakest section is the future work. It should provide a list of possible extensions for each chapter. Throughout this review, comments have been left that could expand this list.

-The IPIN 2023 conference paper's publication status must be updated as it still shows “Accepted for publication”. I understand that the proceedings have already been published.

References.

-The Wikipedia should not be used as a scientific reference. Please use alternative sources for Half-precision and CUDA concepts.

The thesis presented here fulfils all the necessary requirements for its defence as it comprehensively covers all the essential aspects of the proposed research. However, some aspects require attention before the final presentation. Addressing the listed issues will significantly improve the overall strength and coherence of the thesis, resulting in a successful defence.

Castelló de la Plana –
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