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Thesis Changes Log

Name of Candidate: Viktor Rakhmatulin

PhD Program: Engineering Systems

Title of Thesis: DNN-Driven Autonomous Robotic System for Vision-Guided Plug-In Charging of Electric Vehicles in Complex Lighting Conditions and Human Presence

Supervisor: Associate Professor Dzmitry Tsetserukou

The thesis document includes the following changes in answer to the external review process.

I would like to express my gratitude to the reviewers of my PhD thesis for their time and effort. Your invaluable suggestions have greatly enhanced the quality of the work.

Professor Jiwen Lu

- **Comment related to the Literature review: A more detailed discussion on the limitations of specific existing methods in complex outdoor lighting conditions would enhance the depth of the review, establishing a stronger foundation for the research gap this thesis aims to address.**
- **Response:** Thank you for highlighting the need for a more detailed discussion. The subsections related to pose estimation methods have been revised to highlight the limitations of existing techniques in outdoor settings for charging socket pose estimation.

- **Comment related to the Methodology: The robustness of the approach could be further evaluated by considering additional, uncontrolled lighting conditions, such as sudden changes in lighting or high-reflective surfaces. Including these would offer insights into how well the system can adapt in diverse, dynamic outdoor environments.**
- **Response:** Thank you for highlighting the importance of testing the system under additional, uncontrolled lighting conditions. I acknowledge that scenarios such as sudden lighting changes or high-reflective surfaces represent critical challenges for robotic systems operating in dynamic outdoor environments. In response to your suggestion, the methodology discussion has been extended to explicitly acknowledge this limitation and outline potential avenues for addressing it in future research.

- **Comment to Experimental Design and Results: One limitation is the limited discussion on system performance over prolonged usage or in large-scale deployments. Adding data on system reliability over extended periods and potential challenges during long-term operation would add further practical insights.**
- **Response:** Thank you for highlighting this important aspect. The discussion and future work sections have been expanded to emphasize the significance of evaluating system performance over prolonged usage and in large-scale deployments.
- The scope of the current study was defined to address specific challenges, such as complex lighting conditions and dynamic human-robot interactions, within controlled environments. Due to resource constraints, industrial-scale integration and long-term reliability testing were not conducted. However, these factors are recognized as critical areas for future exploration.

- Proposals for future work include collaborative efforts with industry stakeholders to enable extensive evaluations in real-world deployments, providing insights into the system's performance over extended periods. Additionally, integrating predictive maintenance strategies and self-diagnostic mechanisms could improve system resilience and reliability, supporting scalable and long-term industrial applications.

- **Comment to Contributions and Impact: Future studies could explore system scalability, especially in urban settings with multiple robots or more complex human activity around charging stations. Analyzing the scalability of the proposed system will determine its feasibility for broader urban deployment.**
- **Response:** Thank you for the suggestion. The future work section has been updated to include an emphasis on system scalability. Potential areas for investigation include evaluating the system's performance in urban settings with multiple robots operating simultaneously and addressing challenges posed by increased human activity around charging stations. These considerations will help determine the feasibility of broader urban deployments.

- **Comment: Minor language enhancements and additional explanations for technical terms would improve readability, especially for a non-specialist audience.**
- **Response:** Thank you for the constructive feedback. The manuscript has been revisited to improve clarity and ensure technical terms are adequately explained. These revisions aim to enhance readability for both specialists and non-specialists.

Professor Yiyi Liao

- **Comment: Page 24: "Hypotheses 1" -> "Hypothesis 1"**
- **Response**: Thank you for pointing out the typo. I have corrected "Hypotheses 1" to "Hypothesis 1" in the manuscript. In addition, I have reviewed the text thoroughly to identify and rectify any similar typographical errors to ensure accuracy and consistency throughout the document.

- **Comment: The title of this thesis is "DNN-driven Robotic System for Automatic Charging of Electric Vehicles in Complex Lighting Conditions and Human Presence". It appears that only the method proposed in Sec. 3 is related with DNN. The title appears to be slightly misleading in this case.**
- **Response**: Thank you for pointing this out. I have updated the title to better align with the scope of the thesis: "DNN-Driven Autonomous Robotic System for Vision-Guided Plug-In Charging of Electric Vehicles in Complex Lighting Conditions and Human Presence."
- This revision clarifies that the DNN is a key component of the vision system enabling plug-in charging, while the broader contributions of the autonomous system in challenging environments are also emphasized. I hope this resolves any confusion and provides a clearer connection between the title and the thesis content.

Professor Tatiana Podladchikova

- **Comment: Model limitations. The candidate should provide more details on the limitations of the current system, such as potential challenges in high-density pedestrian environments or edge cases in pose estimation.**
- **Response**: Thank you for your valuable feedback. I have addressed this concern by expanding the discussion of model limitations in the concluding chapter. Specifically, I have mentioned limitations related to high-density pedestrian environments, such as difficulties in real-time multi-person tracking, distinguishing between individuals, and maintaining safety feedback accuracy amidst occlusions and sudden changes in crowd density. Additionally, I have mentioned edge cases in pose estimation, particularly under extreme lighting conditions, such as glare, shadows, or rapid illumination changes.

- **Comment: Comparative Analysis. A more detailed comparison with other existing autonomous EV charging systems would strengthen the research context and provide better insight into the unique contributions of the proposed solution.**

- **Response**: Thank you for identifying this opportunity to enhance the research context. I have incorporated a table in the introduction section that highlights the core distinctive features of competing EV charging solutions, offering a concise overview of their strengths and limitations. Furthermore, I have included a comparative analysis of the performance of existing research on autonomous EV charging systems in Section 3, emphasizing the unique contributions of the proposed solution, such as its adaptability to complex urban environments and enhanced safety mechanisms.

- **Comment: Future Applications. Additional discussion on the applicability of the developed methodologies in other robotic applications could further emphasize the broader impact of the work.**
- **Response**: Thank you for your suggestion. I have introduced a detailed "Future Applications" subsection to highlight the broader impact of the methodologies developed in this research. This subsection explores the potential for applying the proposed pose estimation framework, dataset annotation techniques, and safety measures to a range of robotic applications. Examples include automated fueling, wireless charging alignment, accessibility solutions for individuals with disabilities, and applications in industrial, and augmented reality contexts. These additions emphasize the versatility and broader societal relevance of the work.

- **Comment: The abstract would be enhanced by a clearer, more concise problem statement that highlights the novelty, relevance, and core focus of the research to strengthen its impact and establish a well-defined context for the defense. Similarly, refining the conclusions to explicitly underscore the achievements—emphasizing the innovation and broader implications of the findings—would ensure that the contributions are well-situated within the current robotics research landscape.**
- **Response:** Thank you for the insight. I've elaborated the problem statement in the abstract and expanded the future applications section to emphasize practical contributions and innovations of the current thesis.

Professor Clement Fortin

- **Comment: My main question about the thesis is about the order of the research questions. It appears to me that question 2 is the main question of the thesis and question 1 is part of it. The main contribution of the research work is about improving Human Robot Interaction as it is presented in the conclusion. The EV insertion topic is a particular use case of this more general objective of the thesis.**
- **Response:** Thank you for your insightful comment. I understand how the current presentation of the research questions might create some confusion regarding their relative importance. To address this, I have revisited the thesis to better articulate its central focus: the development of an autonomous robotic system that operates reliably in complex lighting conditions while ensuring safe Human-Robot Interaction in human-populated environments. These are critical factors for deploying autonomous systems in urban contexts.
- With this broader vision in mind, both research questions are equally important and complementary. The first question focuses on achieving robust operational functionality, while the second emphasizes the development of safety measures for effective and secure HRI. The EV insertion task serves as a representative use case, demonstrating how these two aspects—reliable operation and safe interaction—are integrated to address the challenges of real-world applications.

- **Comment: In section 4.2, the definition of the acronym HAD must be presented at the beginning, as in the title of the section.**
- **Response:** Thank you. I've corrected this issue and reiterated throughout the thesis to correct more typos, language related issues, and glossary stuff.
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Professor Gonzalo Ferrer

- **Comment: The manuscript has been improved since last time I reviewed as an IDC member, expanding the introduction and some materials in the motivation, problem**

statement as well as content chapters. It is adding more references to relevant works trying to give a wider view of the problem studied.

- **Response:** Thank you for the acknowledgement of the committed improvements. I've revisited the manuscript again to improve the clarity and correctness of the text.