Lancaster University School of Computing and Communications

Third Year Project Report

Title Page

Evaluating and Communicating the Reliability of Data from Wearable Devices for Health Tracking

Date of Submission:

Declaration of Originality

I certify that the material contained in this dissertation is my own work and does not contain unreferenced or unacknowledged material. I also warrant that the above statement applies to the implementation of the project and all associated documentation. I consent to this being stored electronically and copied for assessment purposes, including the school's use of plagiarism detection systems in order to check the integrity of assessed work. I agree with my dissertation being placed in the public domain, with my name explicitly included as the author of the work.

Name: Leo Leung Hei

Date:

Abstract

[To be completed after finishing - 200 words maximum]

This should include:

- 1-2 sentences on aims: Evaluating wearable device data quality and developing visualization strategies for clinicians and consumers

- 1-2 sentences on implementation: Data quality assessment framework with completeness, on-body detection, and signal quality metrics, plus interactive dashboard

- 2-3 sentences on findings: [Complete after user study]

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1 Introduction

The growth of wearable health devices has changed personal health monitoring, enabling continuous tracking of physiological metrics including heart rate, sleep patterns, physical activity, and other biometric data. However, the reliability of data collected by these devices remains a significant concern that directly changes clinical decision-making, user trust, and the overall utility of wearable technology. This project addresses the need for transparent communication of data quality to both healthcare professionals and end-users through the development of a comprehensive quality assessment system and intuitive visualization interfaces.

1.1 Overall Aim of the Project

The primary aim of this project is to investigate the reliability of wearable device data through systematic quality assessments and to develop effective visualization strategies that communicate data uncertainty to both clinical professionals and consumers. The developed system evaluates data across multiple quality dimensions and presents reliability information through interactive visualizations tailored to different user's expertise levels.

1.2 Problem Overview

Research has shown substantial data quality issues across wearable devices that affect their clinical utility. Studies show that data completeness varies significantly depending on recording methods, with streaming approaches experiencing up to 49% data loss compared to just 9% for onboard storage. Signal quality varies widely by sensor type, with blood volume pulse (BVP) measurements showing the lowest reliability at a mean quality score of 60.2%, followed by electrodermal activity (EDA) at 70.4%, while temperature measurements prove most reliable at 96.1%.

Consumer-grade wearables show variable accuracy across different biometrics. Heart rate measurements often underestimate actual values by 7-9 beats per minute during exercise; step counts show 9-24% error rates, and energy expenditure calculations display 6-43% error rates. These inconsistencies raise concerns about the suitability of using such data for medical decision-making without clear communication of uncertainty.

Furthermore, healthcare professionals often lack training in interpreting wearable data, while consumers may over-rely on device metrics without understanding their limitations. This knowledge gap highlights the need for transparent communication of data quality that adapts to the user's technical ability.

1.3 Project Motivation and Significance

The main motivation for this project stems from the growing integration of wearable devices into healthcare settings and personal health management, despite persistent concerns about data reliability. Without clear communication of data quality, clinicians risk making decisions based on unreliable information, and consumers may develop inappropriate health behaviors based on inaccurate measurements.

This project is significant because it bridges the gap between technical data quality assessment and user-facing communication. By developing both the algorithmic framework for evaluating data quality and the interface for communicating uncertainty, this work contributes to safer and more informed use of wearable health technology. The insights gained will help set up the best practices for uncertainty visualization in both health contexts, and advance understanding of human-computer interaction for viewing health data interfaces.

1.4 Project Aims and Objectives

- Create a Data Quality Assessment Framework: Develop a comprehensive framework to evaluate wearable device data across multiple metrics including data completeness, on-body detection, and signal quality assessment, implementing algorithms adapted from established research methodologies.

- Design Uncertainty Visualization Techniques: Designing and implementing multiple visualization approaches to communicate uncertainty effectively, including confidence intervals, color-coded quality indicators, density plots, and interactive time-series displays, with adaptive complexity based on user ability.

- Build an Interactive Dashboard: Develop an interactive web-based dashboard integrating the quality assessment framework with specialized visualizations, displaying wearable device data alongside reliability indicators and allowing users to explore quality variations over time and across sensor modalities.

- Evaluate Effectiveness Through User Studies: Conduct user evaluation through task-based usability testing with 5-20 participants to assess whether users can correctly interpret uncertainty data, whether reliability communication affects trust, and whether visualizations support better decision-making.

1.5 Report Structure

Chapter 2 provides background on data quality evaluation methodologies, uncertainty visualization techniques, and related research on wearable device reliability. Chapter 3 presents the requirements of analysis and design decisions for both the quality assessment framework and visualization interface. Chapter 4 details the implementation of the system, including algorithm development, dashboard construction, and technical challenges met. Chapter 5 describes the evaluation methodology and presents results from user studies assessing system effectiveness. Chapter 6 concludes by reviewing whether project aims were met, discussing lessons learned, and proposing future work directions.

1.6 Summary

This chapter introduced the problem of data quality in wearable health devices and outlined the project's aim to develop a system that evaluates and communicates data reliability effectively.

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2 Background

This chapter examines the technical context and related research that forms the foundation for this project. It discusses institutionally developed work on data quality evaluation in wearable devices, uncertain communication in health conte1xts, and human-computer interaction principles for health data interfaces.

2.1 Technical Context

Data quality evaluation in wearable monitoring devices requires multi-dimensional assessment approaches that account for various sources of unreliability. An institution developed a comprehensive framework for evaluating data quality from the Empatica E4 wristband used in epilepsy monitoring [3]. Their method assessed quality across three primary dimensions: data completeness (whether expected samples were recorded), on-body detection (whether the device was actually worn), and signal quality (reliability of physiological measurements).

The framework employed sensor-specific signal processing techniques tailored to each data modality. For BVP data, spectral entropy calculations showed periods of poor signal quality, revealing that BVP had the lowest reliability among all modalities with a mean quality score of only 60.2%. EDA evaluation used rate of amplitude change analysis, achieving 70.4% mean quality. Temperature measurements were most reliable at 96.1% mean quality, while accelerometer data was evaluated through threshold-based algorithms for detecting device removal.

Critically, the study proved that data collection methods significantly affect completeness, with streaming approaches losing up to 49% of data compared to 9% loss for onboard storage. This finding has important implications for real-time monitoring applications and highlights the need for quality assessment systems that can show and communicate these reliability variations.

Uncertainty in health wearables arises from multiple sources including sensor limitations, algorithmic processing decisions, contextual factors e.g. device placement and user activity, and individual physiological differences. Research by Knowles identified that these uncertainties are often invisible to users, leading to potential misinterpretation of data [4]. The work emphasized that both healthcare professionals and consumers require appropriate training and tools to understand the limitations of wearable data.

Uncertainty visualization represents a challenging domain within information visualization. Effective uncertainty communication must balance providing sufficient information for informed decision-making while avoiding overwhelming users with technical details. In health contexts, this challenge is amplified because decisions based on uncertain data can have significant consequences for wellbeing.

2.2 Related Work and Existing Systems

[Discussion of relevant work and/or existing related systems. Include discussion of their implications for your project, such as improvements your system offers or shortcomings your work addresses]

2.3 Justification of Design Choices

[Justify your choice of platform, software, solution, etc.]

2.4 Summary

[Brief summary of the chapter and link to next chapter]

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3 [Insert Chapter Title - e.g. Requirements and Design]

[Short passage describing what this chapter is about]

3.1 [Insert section title]

[Content]

3.2 [Insert section title]

[Content]

3.x Summary

[Brief summary of the chapter and link to next chapter]

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4 [Insert Chapter Title - e.g. Implementation]

[Short passage describing what this chapter is about]

4.1 [Insert section title]

[Content]

4.2 [Insert section title]

[Content]

4.x Summary

[Brief summary of the chapter and link to next chapter]

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5 [Insert Chapter Title - e.g. Evaluation]

[Short passage describing what this chapter is about]

5.1 [Insert section title]

[Content]

5.2 [Insert section title]

[Content]

5.x Summary

[Brief summary of the chapter and link to next chapter]

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6 Conclusions

[Short passage describing what this chapter is about]

6.1 Review of Aims

[Revisit objectives from Introduction. For each, analyse whether the project met that objective, and if not, discuss this and suggest a solution]

6.2 Suggested Revisions to Design/Implementation

[Discuss if you did it again would you do it differently?]

6.3 Lessons Learned

[What did you have to learn to do the project? What did you learn from doing it?]

6.4 Future Work

[What would you do if you had more time? Possible developments of existing system]

6.5 Overall Conclusion

[Brief, positive overall conclusion on the project as a whole]

References

[3] Böttcher, S., Vieluf, S., Bruno, E., Joseph, B., Epitashvili, N., Biondi, A., Zabler, N., Glasstetter, M., Dümpelmann, M., Van Laerhoven, K., Nasseri, M., Brinkman, B.H., Richardson, M.P., Schulze-Bonhage, A. and Loddenkemper, T. (2022). Data quality evaluation in wearable monitoring. *Scientific Reports*, [online] 12(1), pp.1–16. doi: https://doi.org/10.1038/s41598-022-25949-x

[4] Knowles, B. (2018). Uncertainty in Current and Future Health Wearables – Communications of the ACM. *Acm.org*. [online] doi:https://doi.org/10.1145//3199201.

Appendix A: Original Project Proposal

[Insert your original project proposal from Michaelmas term - do not edit]

Appendix B: [Insert Title]

[Insert supplementary material such as code excerpts, questionnaires, interview transcripts, participant information sheets, consent forms, graphs, or visualisations]

Formatting Notes

- **Font:** Times New Roman or Computer Modern, minimum 12pt, single-spaced
- **Maximum length:** 12,000 words (excluding front matter, references, and appendices)
- **Chapter structure:** Each chapter starts on new page; sections do NOT start on new page unless necessary
- **Subsection numbering:** x.1, x.2, etc.; x.1.1, x.1.2, etc. (do not go deeper than x.1.1)
- **Figures:** Number as Figure x.1, Figure x.2, etc. Include captions and refer to in text
- **Tables:** Number as Table x.1, Table x.2, etc. Include captions and refer to in text
- **References:** Use only one referencing style throughout (Harvard or IEEE recommended)
- **Page numbers:** All pages numbered
- **Ethics:** If your project involved human participants, include ethics application, participant consent form, and information sheet with submission

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Key Reminders

- Discuss report structure with your supervisor to suit your specific project type
- Quality over quantity—avoid waffle and irrelevancies

- Start writing early and allow plenty of time for supervisor feedback and revisions
- First draft deadline: Monday of Week 18
- Final submission deadline: 4pm Friday Week 21 on Moodle
- Submit report as PDF plus working documents (code, results, etc.) as archive file