AN INCLUSIVE INDOOR WAYFINDING SOLUTION FOR PEOPLE WITH VISUAL IMPAIRMENT

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JULY 2023

An Inclusive Indoor Wayfinding Solution For People With Visual Impairment

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Submitted

in fulfilment of the requirements of the Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

JULY 2023

THESIS CERTIFICATE

This is to certify that the thesis titled **An Inclusive Indoor Wayfinding Solution For People With Visual Impairment**, submitted by **Vikas Upadhyay (2018ANZ8059)**, to the Indian Institute of Technology, Delhi, for the award of the degree of **Doctor of Philosophy**, is a bona fide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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Date: July 2023

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor Prof. M. Balakrishnan, for his unwavering support, guidance, and invaluable insights throughout the course of my research. His constructive feedback and critical analysis played a pivotal role in shaping this thesis and helped me refine my ideas. I would also like to extend my thanks to Prof. PVM Rao, and Dr. Rohan Paul, Dr. Piyush Chanana who provided me with their invaluable advice, support, and encouragement throughout my academic journey. Their timely assistance and motivation helped me overcome numerous challenges and inspired me to pursue excellence.

I would also like to thank my colleagues and friends for their unwavering support and valuable feedback. Their encouragement, motivation, and support have been a constant source of inspiration throughout my academic journey. I am also thankful to the project staff, user organizations, fellow students, volunteers like Deepak, Akashdeep, and participants who took part in the research. I am thankful to fellow lab mates from Assistech - Pulkit and Suman, project staff - Pankaj and Mishor, and Other colleges Gulshan, Tigmanshu, and Pranay. I am also thankful to Assistech Lab and the Departmental administrative team Sunita, Rajesh Sir, and S.D. Sharma Sir for extending their unconditional support.

I also extend my special thanks to Dr. Shakti Gupta, AIIMS Jammu, and Dr. Innayat Kabit for their generous support to conduct pilot trials at Dr. RP Center, AIIMS New Delhi. I am also thankful to other organizations WHO-SEARO and Prof. Kalpana Bhakuni, Kamala Nehru College for their support in conducting Pilot trials. I would like to extend my acknowledgment to our focus group participants who were the major stakeholder in our need assessment exercise. This includes Dr. Dipendra Manocha from Shakrshm Trust, Dr. Sam Taraporwala from XRCVC, Mumbai, Dr. Homiyar Mobedji from Bookshare, Prashant Ranjan Verma from NAB RK Puram, Pranav Lal, Yogesh Taneja, Sonali, and Dr. Naresh from Kamala Nehru College and many more. Later part of my research, visiting the Global Disability Innovation (GDI) HUB at UCL has been instrumental in refining and testing my proposed system in a new setting. I would like to extend my gratitude to the Newton Bhabha Fund, Dr. Cathenine Halloway (Professor at GDI HUB, UCL), as well as Danial and Albert from UCL for their exceptional support in making this visit a success.

Finally, I would like to express my sincere gratitude to my parents. Their unwavering love, encouragement, and support have been a constant source of strength throughout my Ph.D. journey. Their support has played a crucial role in my ability to persevere in my research. Without their assistance, I would not have been able to achieve this milestone.

ABSTRACT

In recent years, outdoor navigation has been highly successful, but indoor wayfinding and accessibility continue to pose significant challenges worldwide. Rapid complexity including size growth within indoor spaces has increased the volume of information, while simultaneously making availability, accessibility, and maintainability more difficult. This study aims to address indoor wayfinding and accessibility issues at a deeper level, with a focus on creating sustainable technology solutions that understand, analyze and annotate building maps to address inclusion within indoor spaces. The proposed research focuses on two complementary problems to create more accessible indoor spaces for all; low-resource countries and people with visual impairments. Our investigation found, built environments provide ample cues to support wayfinding and accessibility for visitors. Technology can capture, highlight, or redefine these cues in a more inclusive and transparent way through indoor maps. Our first solution focuses on inclusive mapping needs and offers an easy and scalable mapping mechanism for indoor spaces. These maps contain relevant information and are the basis to support wayfinding and accessibility. Indoor wayfinding and accessibility refer to a user's ability to navigate and access points of interest and associated services independently. Our positioning solution can pinpoint the user's location in real time over indoor maps and deliver relevant information and services via smartphones. The second solution addresses the wayfinding and accessibility needs by providing an accessible application interface to navigate and access complex indoor spaces. Finally, we have formulated two major reports as an outcome of this research. First is an open information specification that provides a semantic taxonomy of indoor information. The second report includes a standard operating procedure to implement or retrofit a multi-model intervention to any old or new building to make them navigation and accessible for a heterogeneous group of visitors. The proposed solutions have undergone pilot testing at three distinct venues, covering over 50,000 square meters of indoor spaces. We believe that an appropriate translation and implementation approach can enhance the utility of this research outcome, thus increasing the coverage of inclusive indoor maps and their accessibility.

सार

हाल के वर्षों में, आउटडोर नेविगेशन अत्यधिक सफल रहा है, लेकिन इनडोर वेफ़ाइंडिंग और पहुंच दुनिया भर में महत्वपूर्ण चुनौतियों का सामना कर रही है। इनडोर स्थानों के भीतर आकार वृद्धि सहित तीव्र जटिलता ने जानकारी की मात्रा में वृद्धि की है, साथ ही उपलब्धता, पहुंच और रखरखाव को और अधिक कठिन बना दिया है। इस अध्ययन का उद्देश्य इनडोर स्थानों के भीतर समावेशन को संबोधित करने के लिए भवन मानचित्रों को समझने, विश्लेषण करने और एनोटेट करने वाले टिकाऊ प्रौद्योगिकी समाधान बनाने पर ध्यान केंद्रित करने के साथ इनडोर वेफाइंडिंग और पहुंच संबंधी मुद्दों को गहरे स्तर पर संबोधित करना है। प्रस्तावित शोध सभी के लिए अधिक सुलभ इनडोर स्थान बनाने के लिए दो पूरक समस्याओं पर केंद्रित है; कम संसाधन वाले देश और दृष्टिबाधित लोग। हमारी जांच में पाया गया, निर्मित वातावरण आगंतुकों के लिए रास्ता खोजने और पहुंच में सहायता करने के लिए पर्याप्त संकेत प्रदान करते हैं। प्रौद्योगिकी इनडोर मानचित्रों के माध्यम से इन संकेतों को अधिक समावेशी और पारदर्शी तरीके से पकड़ सकती है, उजागर कर सकती है या फिर से परिभाषित कर सकती है। हमारा पहला समाधान समावेशी मानचित्रण आवश्यकताओं पर केंद्रित है और इनडोर स्थानों के लिए एक आसान और स्केलेबल मानचित्रण तंत्र प्रदान करता है। इन मानचित्रों में प्रासंगिक जानकारी होती है और ये रास्ता खोजने और पहुंच का समर्थन करने का आधार हैं। इनडोर वेफ़ाइंडिंग और एक्सेसिबिलिटी उपयोगकर्ता की रुचि के बिंदुओं और संबंधित सेवाओं को स्वतंत्र रूप से नेविगेट करने और एक्सेस करने की क्षमता को संदर्भित करती है। हमारा पोजिशनिंग समाधान इनडोर मानचित्रों पर वास्तविक समय में उपयोगकर्ता के स्थान को इंगित कर सकता है और स्मार्टफोन के माध्यम से प्रासंगिक जानकारी और सेवाएं प्रदान कर सकता है। दूसरा समाधान जटिल इनडोर स्थानों को नेविगेट करने और उन तक पहुंचने के लिए एक सुलभ एप्लिकेशन इंटरफ़ेस प्रदान करके रास्ता खोजने और पहुंच संबंधी आवश्यकताओं को संबोधित करता है। अंत में, हमने इस शोध के परिणाम के रूप में दो प्रमुख रिपोर्ट तैयार की हैं। पहला एक खुला सूचना विनिर्देश है जो इनडोर जानकारी का अर्थपूर्ण वर्गीकरण प्रदान करता है। दूसरी रिपोर्ट में किसी भी पुराने या नए भवन में मल्टी-मॉडल हस्तक्षेप को लागू करने या फिर से स्थापित करने के लिए एक मानक संचालन प्रक्रिया शामिल है ताकि उन्हें आगंतुकों के एक विविध समूह के लिए नेविगेशन और सुलभ बनाया जा सके। प्रस्तावित समाधानों का तीन अलग-अलग स्थानों पर पायलट परीक्षण किया गया है, जिसमें 50,000 वर्ग मीटर से अधिक इनडोर स्थान शामिल हैं। हमारा मानना है कि एक उपयुक्त अनुवाद और कार्यान्वयन दृष्टिकोण इस शोध परिणाम की उपयोगिता को बढ़ा सकता है, जिससे समावेशी इनडोर मानचित्रों का कवरेज और उनकी पहुंच बढ़ सकती है।

Contents

List of Tables

List of Figures

ABBREVIATIONS

IITD	Indian Institute of Technology, Delhi
BIM	Building Information Model
PVI	People With Visual Impairment
POI	Point of Interest
LBS	Location Based Services
CRS	Coordinate Reference System
IFC	Industry Foundation Classes
FME	Format Exchange Tool
SOP	Standard Operating Procedure
GPS	Global Positioning System
IMU	Inertial Measurement Unit
PDR	Pedestrian Dead Reckoning
UWB	Ultra-wideband Beacon
OSM	Open Street Map
AT	Assistive Technology
LOD	Level of Details
PWD	Persons with Disability
JSON	JavaScript Object Notation
VGI	Volunteer Geographical Information
RSSI	Received Signal Strength Indicator
IPS	Indoor Positioning System
GPR	Gaussian Process Regression
OPD	Outpatient Department
BLE	Bluetooth Low Energy
IncluMap	The Indoor mapping framework
IncluNav	The Indoor navigation framework