ICORIS 2022

The 4th International Conference on Cybernetics and Intelligent System

Kampus Merdeka

UNIVERSITAS POTENSI UTAMA

04th ICORIS INTERNATIONAL CONFERENCE

Conference ON

08-09 OCTOBER 2022

VENUE: HOTEL KHAS PARAPAT, LAKE TOBA NORTH SUMATERA - INDONESIA

HOST

CO-HOST

SUPPORTED BY

2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) | 978-1-6654-5395-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICORIS56080.2022.10031444

PREFACE

Assalaamu ‘alaykum warahmatullahi wabarakaatuh,

After three successful sessions of ICORIS’s conference, we are proud to present the fourth edition of ICORIS. We believe that ICORIS 2022 is an excellent and exceptional opportunity which enables researchers to present and discuss the latest innovations, results and developments in their research topics. This years’ theme is "Build a trusted infrastructure system with blockchain technologies for society 5.0". The conference is expected to strengthen collaboration and provide a forum for academicians, professionals and researchers to discuss and exchange their research results, innovative ideas, and experiences to advance the field of Information Technology, Information Systems and Electronic Engineering in the modern world. The event will incorporate extensive discussions and consist of additional workshops, guest speaker sessions, and scintillating social events that will help our future leaders develop networks and transform their ideas into actions.

The ICORIS 2022 is in the general area of communication and information technology. It provides a forum for presenting and discussing the latest innovations, results, and developments in IT Management & organizations, IT Applications, Cyber & IT Security, and ICT. We present several tracks that are separated into nine thematic areas, each ICORIS 2022 track is a carefully curated selection of sessions and activities focused on an important current or emerging issue. There is 282 papers submission and only 106 papers are accepted to be presented in this Conference. The accepted papers will be presented in one of the regular sessions and will be published in the conference proceedings volume. All accepted papers are submitted to IEEEXplore. IEEE Conference Number: #56380.

On behalf of the ICORIS 2022 committee, we wish to extend our warm welcome and would like to thank all Keynote Speakers, Reviewers, Authors, and Committees, for their effort, guidance, contribution and valuable support.

Wa billahi taufiq wal hidaayah.

Wallahul muwaffiq ila aqwamit-tharieq.

Wasalaamu ‘alaykum warahmatullahi wabarakaatuh.

Husni Teja Sukmana, Ph.D

2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) | 978-1-6654-5395-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICORIS56080.2022.10031587

THE COMMITTEE OF ICORIS 2022

STEERING COMMITTEE

1. Dr. Y. Johny W. Soetikno, SE.,MM. (Universitas Dipa Makassar, Indonesia)
2. Marthen Sengkey, PhD (Universitas Klabat)
3. Dr. Dadang Hermawan (ITB STIKOM Bali)
4. Dr. Ir. Djoko Soetarno, D.E.A (Binus University)
5. Prof. Dr. M. Suyanto, MM. (AMIKOM Yogyakarta)
6. Prof. Dr. Ir. Harjanto Prabowo, M.M. (Rektor Universitas Bina Nusantara)
7. Prof. Dr. Ir. Edi Noersasongko, M.Kom (Universitas Dian Nuswantoro Semarang)
8. Dr. Sandy Kosasi, MM., M.Kom. (STMIK Pontianak)
9. Dr. Rika Rosnelly, S.Kom., M.Kom. (Universitas Potensi Utama)
10. Restu Adi wiyono, M.Sc., M.Kom. (STMIK Tasikmalaya)
11. Dr. Po Abas Sunarya, M.Si. (STMIK Raharja)
12. Dr Berlilana , M.Kom (Univ Amikom Purwokerto, Indonesia)
13. Dr Anthony Anggrawan, M.T., PhD (Univ Bumigora Mataram, Indonesia)
14. Mus Aidah, S.Pd., MM. (STMIK Adhi Guna Palu)
15. Djuniharto, S.Kom., M.Kom(stmik PGRI, banyuwangi, Indonesia)
16. Dr. Hj. Rosiyati Mh Thamrin, SE., MM. (STMIK Sepuluh Nopember Jayapura)
17. M Hari Purwidiantoro, S.Kom., M.Kom(STMIK AMIKOM Surakarta, Indonesia)
18. Muchammad Naseer, M.Kom (STT Bandung, Indonesia)
19. Benedictus Effendy, ST., MT (STMIK Palcomtec Palembang, Indonesia)
20. Dr. Hadi Santoso, S.Kom., M.Kom.(Institut Sains dan Bisnis ATMALUHUR, INdonesia)
21. Suardi B Haruna, S.Si.,M.Si (STMIK PROFESIONAL, Makasar, Indonesia)
22. Bob Subhan Riza, S.T, M.Kom (Universitas Potensi Utama, Medan, Indonesia)

PROGRAM COMMITTEE

1. Prof. Riyanarto Sarno, Ph.D. (Institut Teknologi Sepuluh Nopember (ITS)), Indonesia
2. Prof. Pitoyo Hartono (Chukyo University, Toyota), Japan
3. Prof. Harold Boley (Faculty of Computer Science, University of New Brunswick, NB), Canada
4. Prof. Eko Sediyono, PhD (Universitas Satya Wacana, Indonesia)
5. Prof. Agus Buono (IPB University, Indonesia)
6. Prof. Joko Lianto Buliali, Msc, Phd (Institut Teknologi Sepuluh Nopember(ITS)), Indonesia
7. Prof. Ir. Arif Djunaidy M.Sc., Ph.D. (Institut Teknologi Sepuluh Nopember (ITS)), Indonesia
8. Prof. Dr.rer.nat. Achmad Benny Mutiara, Q.N, Ssi, Skom (Universitas Gunadarma), Indonesia

2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) | 978-1-6654-5395-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICORIS56080.2022.10031353

9. Prof. Sri Hartati, M.Sc., Ph.D. (IndoCEIS/UGM)
10. Prof. Dr. Muhammad Zarlis (Universitas Sumatera Utara), Indonesia.
11. Prof. Dr Eri Prasetyo Wibowo, SSi, MMSI (Universitas Gunadarma), Indonesia
12. Rafał Dreżewski, Ph.D. (AGH University of Science and Technology), Poland
13. Assoc. Prof. Huynh Thi Thanh Binh (Hanoi University of Science and Technology (HUST)), Viet Nam
14. Prof. Dr. Mustafa Bin Mat Deris (Universiti Tun Hussein Onn Malaysia (UTHM)), Malaysia
15. Assoc. Prof. Somnuk Phon-Amnuaisuk (Universiti Teknologi Brunei), Brunei Darussalam
16. Amil Ahmad Ilham, ST.,MIT, PhD(Universitas Hasanuddin), Indonesia
17. Daniel Oranova, S.Kom., M.Sc.PD.Eng. (Institut Teknologi Sepuluh Nopember (ITS)), Indonesia
18. Arief Setyanto, S.Si., M.T., Ph.D. (AMIKOM Yogyakarta), Indonesia
19. Dr. Ir. Untung Rahardja, M.T.I.,MM. (Universitas Raharja), Indonesia
20. Andrew Tanny Liem, PhD (Universitas Klabat), Indonesia
21. Husni Teja Sukmana, PhD (Universitas Islam Negeri Syarif Hidayatullah), Indonesia
22. Dr Evi Triandini (ITB Stikom Bali, Indonesia)
23. Dr Kusrini (Univ Amikom Yogyakarta, Indonesia)

Technical Program Committee (TPC)

Chair : Husni Teja Sukmana, Ph.D (UIN Syarif Hidayatullah Jakarta, Indonesia)

C0-Chair : Prof. Dr. Teddy Surya Gunawan (Universitas Potensi Utama, Indonesia)

Organizing Committee

1. Program Chair : Husni Teja Sukmana, PhD. (IEEE Member : 93016632)
2. Co Program Chair : Helmi Kurniawan, M.Kom
3. Publication Chair : Prof. Dr. Teddy Surya Gunawan (IEEE Member : 8286407700)
4. Secretary : Ratih Puspasari, M.kom
5. Treasurer : Linda Wahyuni M.Kom

Editing Team

Husni Teja Sukmana, Ph.D

Edy Victor Haryanto, M.Kom

M. Sadikin, M.Kom

Fujiati, M.Kom

Alfa Saleh, M.Kom

Khairani Puspita, M.Kom

TABLE CONTENT

2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) | 978-1-6654-5395-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICORIS56080.2022.10031582

AUTHOR INDEX

2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) | 978-1-6654-5395-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICORIS56080.2022.10031402

41	Assed Lussak	145,524,534
42	Astari Retnowardhani	1
43	Asti Herliana	446
44	Atim Djazuli	371
45	Azani Cempaka Sari	77,89,139,194
46	B. Herawan Hayadi	83,248
47	Badrul Munir	189
48	Bagus Made Sabda Nirmala	573
49	Baiq Desy Aniska Prayanti	59,181
50	Bambang Leo Handoko	242,258
51	Baskoro Azis	189
52	Bayu Kanigoro	72
53	Bens Pardamean	19,26,32,37,48
54	Berlilana	376
55	Bhupesh Rawat	213
56	Bob Subhan Riza	286
57	Brandon Nicolas Marlim	238
58	Brian Joe Antoni	184
59	Brilly Andro Makalew	13
60	Bryan Anderson	194
61	Bryan Ghilchrist	342
62	Budi Juarto	202
63	Budi Susilo	512
64	Budi Triandi	335
65	Budi Yulianto	54
66	Burhanuddin Damanik	563
67	Candra Ahmadi	63
68	Carles Juliandy	248
69	Cecilia Valenda	217
70	Charles Bronson Harahap	310
71	Christian Kurniawan	13
72	Cisde Mulyadi	97
73	Cuk Tho	103
74	Daevan Martana	295
75	Dandy Pramana Hostiadi	462,486,491,573
76	Dani Suandi	295
77	Danielson Danielson	194
78	Darmeli Nasution	528
79	David Agustriawan	289,614,621
80	David David	436
81	Davis Inde Satya	230
82	Davy Ronald Hermanus	295
83	Debby Sondakh	625
84	Deby Erina Parung	26

85	Delly Minita Asnathasia	348
86	Dendi Anggriandi	409
87	Dendy Rosman	166,172
88	Denis Eka Cahyani	363,568
89	Denny Alvito Ginting	223
90	Deny Adhar	310
91	Desti Syuhada	63
92	Dewi Khairani	401
93	Dian Amirullah	26
94	Dian Pratama Putra	32,37
95	Dianka Wahyuningtias	172
96	Dickson Ryan Jose	305
97	Didik Dwi Prasetya	568
98	Digdo Sudigyo	37
99	Doni Purnama Alamsyah	330,446
100	Dwi Ramadhona	441
101	Dyah Nur'Ainingsih	584
102	Eben Haezar Ekoputra Soegiarto	625
103	Edgard Jonathan Putra Pranoto	72
104	Edi Syahputra	452
105	Edson Yahuda Putra	275
106	Edy Irwansyah	72,184
107	Edy Victor Haryanto S	436
108	Efa Ayu Nabila	207
109	Egi Rehani Triyulinar	568
110	Eiad Yafi	43
111	Eka Diraksa Putra	172
112	Eka Purnama Harahap	213
113	Eko Setyo Purwanto	77,89,139,194
114	Elena Bianca Jap	77
115	Eli Hendrik Sanjaya	363
116	Elmanani Simamora	452
117	Elsa Aditya	83
118	Erfan Hasmin	282
119	Eri Prasetyo Wibowo	584,591
120	Erna Budhiarti Nababan	405
121	Ernastuti Ernastuti	631
122	Esmi Nur Fitri	599,603
123	Eugene Salim Wijaya	77
124	Evi Dewi Sri Mulyani	500
125	Evi Triandini	395
126	Fadhilah Akhbar	568
127	Fahmi Fahmi	528
128	Fairuz Iqbal Maulana	109,424

129	Faisal Amir Harahap	254
130	Faishal Hilmy Maulida	66
131	Faishal Rayyan	580
132	Farah Levyta	172
133	Farrel Nelson Veriano	295
134	Farrikh Al Zami	599,603
135	Fathi Sei Pahangai Akbar	129
136	Fathur Muhammad Haekal	123
137	Faulinda Ely Nastiti	43
138	Febrianta Surya Nugraha	97
139	Felix Indra Kurniadi	359
140	Felix Pherry	359
141	Felix Ratana	518
142	Firah Putri Pratiwi	500
143	Frans Ikorasaki	254
144	Fransiscus Asisi Agung Dwi Prasetyo Prasetyo	66
145	Freddy Triono	166
146	Fredy Purnomo	238,223
147	Gabriel Flavianus	295
148	Gabriel Janes Posumah	547
149	Gede Angga Pradipta	264,430,462,486,491,573
150	Gerry Giovan	342
151	Giovanna Cheryl Wu	129
152	Green Arther Sandag	625
153	Green Ferry Mandias	275
154	Gregorius Gregorius	359
155	Gregorius Natanael Elwirehardja	19
156	Hana Desy Natalina	166
157	Hardianto	310
158	Helmi Kurniawan	254
159	Henderi Henderi	207
160	Hendra Nusa Putra	286
161	Hendri Julian Pramana	500
162	Heri Gunawan	310
163	Herlina Kikin	512
164	Herlinawati Herlinawati	387
165	Herlino Nanang	401
166	Herman Mawengkang	335,353,528,538
167	Herpri Melinia	414
168	Husni Teja Sukmana	401
169	Hustinawaty Hustinawaty	325
170	I Dewa Ayu Eka Yuliani	512
171	I Gede Surya Rahayuda	554
172	I Gusti Made Karmawan	258

173	I Gusti Ngurah Satria Wijaya	395
174	I Gusti Ngurah Wikranta Arsa	608
175	I Ketut Putu Suniantara	395
176	I Komang Agus Ady Aryanto	264
177	I Made Arya Budhi	608
178	I Made Bhaskara Gautama	608
179	I Made Darma Susila	462
180	I Made Liandana	462
181	I Nyoman Rudy Hendrawan	608
182	Ibnu Darmawan	145,524,534
183	Ida Bagus Ananta Wijaya	424
184	Ida Bagus Ananta Wijaya.	109
185	Ida Bagus Maha Indra Prasada	264
186	IGKG Puritan Wijaya ADH	608
187	Ignatius Ronald	139
188	Ina Sholihah Widiati	161
189	Indrajani Sutedja	123
190	Indriana Indriana	330
191	Irmawan Rahyadi	441
192	I-Shyan Hwang	270
193	Ivan Diryana Sudirman	330
194	Ivan Gananjaya	320
195	Ivana Rosaline Tejakusuma	66
196	Iwan Fitrianto Rahmad	368
197	Jason Sebastian Kusuma	72
198	Jay Idoan Sihotang	480
199	Jefri Zulkarnain	419
200	Jeremy Andrew Jayaseputra	89
201	Jesse Owen Theodore Chandra	320
202	Jesslyn Audrey	320
203	Jimmy Moedjahedy	305
204	Jody Joseph	305
205	Joe Yuan Mambu	480
206	Johann Felix Alexander Christanto	320
207	Joko Pebrianto Trinugroho	48
208	Jonathan Audris Heriyanto	230
209	Jonathan Axel Benaya	217
210	Jonathan Kristanto	359
211	Joshua Oktavianus Tarung Johannis	387
212	Joshua Sun	621
213	Josia Sean Audric Santoso	139
214	Jovianto Godjali	230
215	Juan Constantine	63
216	Julian Alifirman Wardana	202

217	Karli Eka Setiawan	19
218	Kelvin Leonardi Kohsasih	248
219	Kenny Thenjono	518
220	Kevin Halim	72
221	Khawen Flawrenxius	194
222	Khodijah Hulliyah	580
223	Kians Azizatikarna	26
224	Kristianto Wijaya	230
225	Kusrini Kusrini	409,419
226	Langlang Gumilar	363,414,568
227	Lenny Christina Nawangsari	166
228	Lenny Suwondo	424
229	Leonardo Jose Gunawan	238
230	Leonardo Leonardo	202
231	Levana Dhia Prawati	176
232	Lidya Laoh	625
233	Lili Tanti	353
234	Lilik Sugiarto	97
235	Lilis Meliana	258
236	Lilis Yuningsih	486,491
237	Lily Leonita	391
238	Lina Listiani	500
239	Linda Wahyuni	310
240	Louis Ricardo Supit	134
241	Lusiana Efrizoni	286
242	M. Hafidz Ariansyah	599,603
243	M. Wahyu Prasetyo	414
244	Made Liandana	573
245	Mahda Karina	176
246	Maie Istighosah	409
247	Marcello Octavyo Anugrahanto	295
248	Marchel Thimoty Tombeng	270
249	Mardhatillah Shanti	6
250	Mario Donald Bani	289,621
251	Martinus Hanung Setyawan	176
252	Masyhur Dungcik	441
253	Matrissya Hermita	325,591
254	Matthew Austin Naibaho	441
255	Maxrizal Maxrizal	59,181
256	Maya Silvi Lydia	353
257	Michael Siek and Ivana Wijaya	153
258	Moch Firmansyah	289,621
259	Moch. Hari Purwidiantoro	114
260	Mochammad Fahlevi	371,391

261	Mochammad Haldi Widianto	217,320,342,506
262	Moehamad Adi Rochmat	631
263	Moeljadi Moeljadi	371
264	Mohammad Prasanto Bimantio	32
265	Mohammad Rezza Pahlevi	419
266	Muammar Sadrawi	289,621
267	Muchammad Farchan	189
268	Muhamad Yusup	207
269	Muhammad Ikhwanul Atha Labib	387
270	Muhammad Khoirul Wiro	409
271	Muhammad Zarlis	83,368,405,528,538,560
272	Mutiara Sovina	254
273	N. Nelis Febriani Sm	500
274	Nadya Natasya	614
275	Nanda Ihsan Pradana	161
276	Nanda Rizqia Pradana Ratnasari	289
277	Nanda Satya Nugraha	32,37
278	Neil Errando Sutrisno	238
279	Ni Luh Gede Pivin Suwirmayanti	264
280	Ni Putu Linda Santiari	554
281	Niccosan	13
282	Ninda Lutfiani	207
283	Nisya Kintan Qumari	63
284	Normi Sham Awang Abu Bakar	580
285	Nurhasanah Nurhasanah	184
286	Nurhidayanto Nurhidayanto	97
287	Nurul Aini	282
288	Nurul Sukma Lestari	166
289	Octara Pribadi	248
290	Oei Angela Christabel Gunawan	223
291	Oktoverano Hendrik Lengkong	541
292	Oliver Oswin Sumady	184
293	Padma Nyoman Crisnapati	457
294	Patriot Muslim	401
295	Po Abas Sunarya	207
296	Poltak Sihombing	563
297	Prince Siachin Pasombaran	547
298	Purnamawati Purnamawati	301
299	Purnawarman Musa	591
300	Putu Desiana Wulaning Ayu	430,486,491
301	Putu Devi Novayanti	457
302	R. A. Sekar Ciptaning Anindya	584
303	Rachmi Kumala Widyasari	342
304	Rafiqa Dewi	405

305	Rafly Ananda Dwi Septian	213
306	Rahmat Syifana Jaelani	202
307	Rahmi Ramadhani	452
308	Raihan Firas Muzhaffar	591
309	Randy Nasuta	184
310	Rara Sativa	441
311	Ray Tommy	13
312	Regina Carmelita Kristofani	6
313	Restu Adi Wiyono	500
314	Reymon Rotikan	547
315	Reynoldus Andrias Sahulata	305
316	Reza Fauzan	387
317	Rhio Sutoyo	129
318	Rhio Sutoyo.	134
319	Riah Ukur Ginting	563
320	Ribka Xantia Kusuma	348
321	Ricky Aurelius Nurtanto Diaz	264,457
322	Rika Rosnelly	468
323	Rionaldo Alviansa Handoyo	223
324	Risma Yulistiani	223,238
325	Rismayani Rismayani	315,480
326	Rissa Rahmania	230
327	Rita Layona	54
328	Ritu Chauhan	43
329	Riza Wulandari	395
330	Robby Kurniawan Harahap	584
331	Robertus Laipaka	512
332	Robet	248
333	Ronny Ronny	436
334	Roslina Roslina	468
335	Roy Rudolf Huizen	462,486,491
336	Rubianto Rubianto	254,468
337	Ryan Juwanda	77
338	Ryan Matthew	289
339	Ryonaldi Maulana	172
340	Said Achmad	129,134
341	Saifullah Saifullah	387
342	Sal Sabila Wijayanti	409
343	Salsa Nabillah	348
344	Samuel Chandra	223
345	Sandy Kosasi	512
346	Sarifuddin Madenda	631
347	Sarjon Defit	286
348	Satria Perdana Putra Prabowo	161

393	Wahyu sardjono	1
394	Wahyu Waskito Putra	189
395	Wanayumini Wanayumini	83
396	Wayan Cahya Ayu Pratami	395
397	Widi Pangestuti	419
398	Widyastuti Widyastuti	584
399	Willy Lau	139
400	Yohanes Priyo Atmojo	462
401	Yohanes Raynaldi Pereira	348
402	Yovanka Davincy Setiawan	342
403	Yovinne Hendro Cipta	109
404	Yovita Tunardi	54
405	Yudhistya Ayu Kusumawati	6,66
406	Yudi Agusta	474
407	Yuni Yuniar	446
408	Yusfrizal Yusfrizal	254
409	Yustikamasy Astica	419
410	Zakarias Situmorang	83
411	Zefany Athalia	506

2022 Fourth International Conference on Cybernetics and Intelligent Systems (ICORIS)

Medan, Indonesia

(Hybrid Conference)

October 08th-09th, 2022

Part Number: CFP22BWC-ART
ISBN: 978-1-6654-5395-0

2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) | 978-1-6654-5395-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICORIS56080.2022.10031589

2022 Fourth International Conference on Cybernetics and Intelligent Systems (ICORIS)

Medan, Indonesia (Virtual)

Phone: +6281263411368

Email: icoris2022@potensi-utama.ac.id

Website: http://icoris.org/

October 08th-09th, 2022

Part Number: CFP22BWC-ART
ISBN: 978-1-6654-5395-0

2022 Fourth International Conference on Cybernetics and Intelligent Systems (ICORIS)

ISBN: 978-1-6654-5395-0

Additional copies of this publication are available from

Curran Associates, Inc.

57 Morehouse Lane

Red Hook, NY 12571 USA

+1 845 758 0400

+1 845 758 2633 (FAX)

Footstep Detection for Indoor Positioning using Accelerometer and Magnetometer Sensor on Smartphone

Made Liandana
Study Program Information Technology
Institut Teknologi dan Bisnis STIKOM Bali
Bali, Indonesia
liandana@stikom-bali.ac.id

Bagus Made Sabda Nirmala
Study Program Information Technology
Institut Teknologi dan Bisnis STIKOM Bali
Bali, Indonesia
sabda@stikom-bali.ac.id

Gede Angga Pradipta
Study Program Information System
Institut Teknologi dan Bisnis STIKOM Bali
Bali, Indonesia
angga_prodipta@stikom-bali.ac.id

Dandy Pramana Hostiadi
Study Program Information System
Institut Teknologi dan Bisnis STIKOM Bali
Bali, Indonesia
dandy@stikom-bali.ac.id

***Abstract*—Indoor positioning using inertial sensors can be used as an alternative to GPS because indoor GPS signals are weaker than outdoors. Inertial sensors such as accelerometers and magnetometers are already packaged in smartphone devices, so the use of smartphones for indoor positioning is an option. Footstep detection is essential in determining position indoors; in this study, footsteps were detected using the accelerometer sensor. While the heading direction is calculated using the Magnetometer sensor. Previous studies have shown that the position of the smartphone, when held, affects indoor positioning estimated. So in this study, it is proposed to use the angle of inclination. In addition, to identify the initial position, a marker in the form of a QR Code is used. The proposed approach consists of 5 processes, namely: calculating the tilt angle, detection of footsteps, calculating the heading direction, estimated displacement, and the estimation of the position. The error in the position estimation is used as a test parameter. The longer path length results in a smaller error than the shorter path.**

Keywords—Indoor positioning, tilt angle, QR code, accelerometer, magnetometer.

I. Introduction

Information about the floor plan is necessary, especially for visitors who visit the building for the first time. The floor plan is usually affixed to the room's wall or a corner of the room. However, the floor plan cannot provide up-to-date information on the position of visitors due to the limited number of floor plans posted in the room and the position of visitors who move, so a navigation system is needed. One navigation system technology is the Global Positioning System (GPS) [1]. However, GPS cannot work properly indoor areas due to signal attenuation caused by building materials [2][3][4]. Thus, a navigation system indoors that does not use GPS is required [4][5][6][7][8][9]. Indoor positioning can be grouped based on its technology, namely: optical technology, sound-based technology, radio frequency, hybrid technology, and passive technology [3]. There are examples of optical-based technologies such as Infrared (IR) and Visible Light Communication (VLC) [10][11]. For sound-based technology can use ultrasonic [12]. Indoor positioning technologies that use radio frequencies such as Wi-Fi [13], Bluetooth [14], ZigBee [15] and RFID [16]. While, passive technology generally uses inertial sensors, such as magnetic or magnetometers [17], accelerometers, and gyroscopes [18].

Indoor positioning that uses an inertial sensor is pedestrian navigation [17][18]. Assuming every visitor to a building is a pedestrian, inertial sensors can be used for navigation systems for visitors in a building. Pedestrian navigation techniques that use inertial sensors are also known as Pedestrian Dead Reckoning (PDR). PDR technique combines step detection, stride length estimation, and user direction estimation [19]. The user's position is updated by adding the current relative displacement estimate to the previous position estimate [19].

The smartphone's size, which is relatively small so that it is easy to carry everywhere, is reasonably practical if used for indoor positioning, especially pedestrian navigation systems. In addition, the smartphone has also been installed with several inertial sensors, such as an accelerometer, gyroscope, magnetometer, and other sensors. The inertial sensor contained in the smartphone does not require particular infrastructure if it is used for indoors positioning [20][21][22]. In pedestrian navigation using the PDR technique, the results of position calculations are very dependent on the carrying position of the smartphone device used by the user [23]. Consequently, the user must maintain the smartphone position. For example, the carrying position smartphone is horizontal. Its carrying position flat must be held while calculating the indoor position so that the sensor readings do not change drastically.

Estimation of stride length and estimation of heading are essential parameters for positioning indoors using the PDR technique [4][23][24][25]. Another study combined these parameters with RSS from Wi-Fi and Bluetooth [26][27]. This study combined stride length estimation and heading estimation with smartphone tilt angle. This tilt angle is calculated based on the acceleration generated by the accelerometer sensor. The current indoor position is identified using the acceleration threshold value, compared with the acceleration value generated by the accelerometer sensor when the user steps. The user's

2022 4th International Conference on Cybernetics and Intelligent System (ICORIS) | 978-1-6654-5395-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/ICORIS56080.2022.10031335

heading uses a compass direction that can be identified using the magnetometer sensor.

II. METHODS

Footstep detection, stride length estimation, and user direction estimation are the main processes in indoor positioning using the PDR technique [19]. In addition, the carrying position of a smartphone is also essential [23]. Therefore, the PDR technique is combined with reading the tilt angle. In this study, the sampling rate of the accelerometer sensor is 60 Hz. The indoor positioning process is shown in Fig 1.

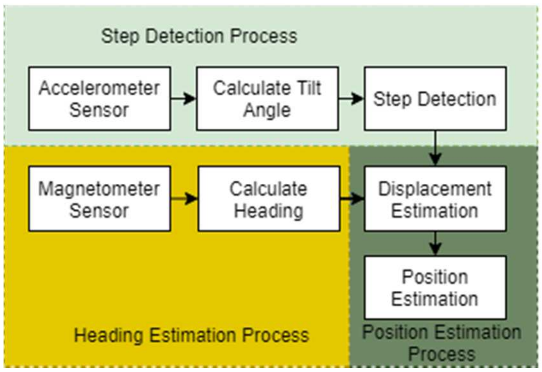

Fig. 1. Indoor Positioning Process

A. Tilt Angle

The acceleration generated by the accelerometer sensor is used to calculate the tilt angle of the smartphone held by the user. The tilt angle can be calculated using Eq. (1), also used in the previous study [28].

$$\theta = tan^{-1}\left(\frac{\sqrt{Ax^2 + Ay^2}}{Az}\right)\ \frac{180}{\pi} \quad (1)$$

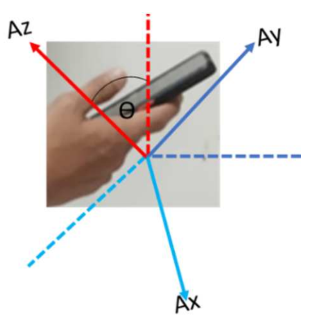

Fig. 2. Til Angle of Smartphone Position

As shown in Fig 2, the dotted line is the direction of the accelerometer sensor's axis (x,y,z); when the smartphone is placed horizontally, the line is used as a reference point. While the arrows indicate the direction of the axis when held by the user. When the user uses a smartphone in a position shown in Fig 2, the resulting angle ranges from 15 to 40 degrees. The angle value is used as the minimum angle threshold value θth_{min} and the maximum angle threshold value θth_{max}.

B. Step Detection

The acceleration generated by the three axes of the accelerometer sensor is used to calculate the Signal Vector Magnitude (SVM). In the previous study [29][30][31], the SVM signal was calculated using equation (2). *Ax, Ay*, and *Az* are accelerometer acceleration values for the x, y, and z axes, while SVM is the square root of the sum of the squares of each axle.

$$SVM = \sqrt{(A_x)^2 + (A_y)^2 + (A_z)^2} \quad (2)$$

Gravity contributes to the acceleration value on each axis of the accelerometer sensor; in this study, the contribution of the value of gravity is reduced by using a filter. Filtering is done by software using the program code provided on the official Android Developer website [32]. Thus, in this study, the SVM value is calculated using equation (3). $SVM_{fil}(i)$ is the square root of the sum of the squares of each filtered axis at the i-th sampling point. Meanwhile, $\mathrm{A}x_{fil}(i)$, $\mathrm{A}y_{fil}(i)$, and $\mathrm{A}z_{fil}(i)$ are the x, y, and z axis acceleration values that have been filtered at the *i* sampling point.

$$SVM_{fil}(i) = \sqrt{(\mathrm{A}x_{fil}(i))^2 + (\mathrm{A}y_{fil}(i))^2 + (\mathrm{A}z_{fil}(i))^2} \quad (3)$$

where i = 1 to 30

Each one-step movement will produce an SMV filter pattern, as shown in Fig.3 (which is flanked by a yellow line); the resulting pattern is in the range of 30 sampling points so that the *i* sampling point in Eq. (2) starts from 1 to 30. The range of sampling points is referred to as the sampling length, denoted by n. The assumption is that all footsteps are steps forward.

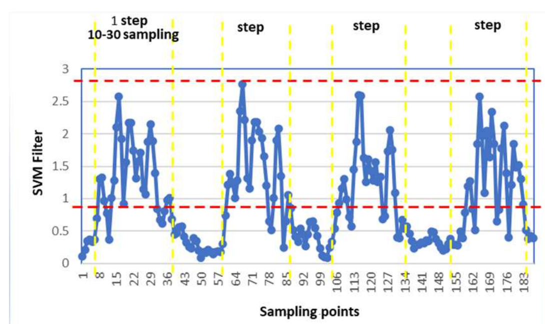

Fig. 3 Sampling of Walking.

In addition to using the SVM filter value, the parameter used to detect footsteps is the difference from the SVM filter, which is calculated using Eq. (4). SVM*diff*(i) is the difference of the SVM filter at the *i* sampling point starting from 1 to n-1.

$$SVM_{diff}(i) = SVM_{fil}(i+1) - SVM_{fil}(i) \quad (4)$$

The value of the SVM filter during one step ranges from 0.8 to 2.75, as shown in Figure 3 (red line), and SVM*diff* is smaller or equal to 2. The value of 0.8 is used as minimum threshold for SVM*thmin*, and the value of 2.75 is the maximum threshold for SVM*thmax* . The flow for detecting a single footstep is as follows:

(1) Read the x, y, and z axis acceleration data from the smartphone's accelerometer sensor.

(2) Calculate the angle of inclination using equation (1).

(3) If $\theta th_{min} \leq \theta \leq \theta th_{max}$, calculate the SVM filter (SVM_{fil}) using Eq. (3). Steps (1) to (3) are repeated so that the number of sampling is equal to n (30 samplings).

(4) Calculate the difference in SVM filter (SVM_{diff}) using Eq. (4).

(5) Trace SVM_{diff} from 1 to n-1 sampling. If there is a difference greater than 2 (threshold), it is possible that the sampling value that has been taken is not a pattern of one footstep, repeat sampling from step (1). However, if the SVM_{diff} difference is less than or equal to 2, go to step 6.

(6) Trace SVM_{fill} from 1st to n sampling. One step is detected if there are 5 to 10 values that meet $SVMt_{hmin} \leq SVM_{fill} \leq SVMth_{max}$ ($COUNT_{upper}$) and there are 3 to 10 values that meet $SVM_{fil} < SVMth_{min}$ ($COUNT_{below}$).

```
Pseudo code step detection method
N (Number of sampling)= 30
θth_min= 15
θth_ma= 40
diff_th=2
WHILE(Read Sensor):
   INPUT: Ax(i), Ay(i), Az(i)(until i=N)
   Calculate Axfil(i), Ayfill(i), Azfill(i)
   FOR i = 1 to N
        Calculate tilt angle θ
        IF θth_min ≤ θ ≤ θth_max THEN
              Calculate SVMfill(i)
        ENDIF
   ENDFOR
   FOR i = 1 to N
     Calculate SVMdiff
     IF SVMdiff(i) < diff_th THEN
        IF SVMth_min ≤ SVMfill(i)  ≤ SVMth_max
                        THEN
              COUNTupper= COUNTupper+1
        ELSEIF SVMfill(i) < SVMth_min THEN
              COUNTbelow=COUNTbelow +1
         ENDIF
     ENDIF
    ENDFOR
    IF (5 > COUNTupper >10)
              AND (3 > COUNTbelow > 10) THEN
      STEP = TRUE
      REMOVE all index of Axi, Ayi, Azi
    ELSE
      STEP= FALSE
      REMOVE first index of Axi, Ayi, Azi
    ENDIF
ENDWHILE
```

C. Calculate Heading

The heading direction of smartphone users is detected using the Magnetometer sensor on the smartphone. The values of the Magnetometer sensor are converted into an azimuth angle. The azimuth value obtained is divided into four parts, as shown in Fig 4, each part is used to estimate the user's heading direction.

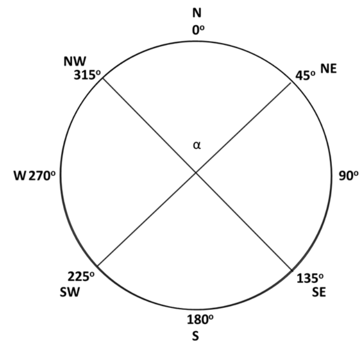

Fig. 4. Azimuth

D. Displacement Estimation

The estimated displacement from one point to the next is known based on detected footsteps. So, the length of the footstep determines how much the value of the displacement that occurs. Therefore, it is necessary to find a way to determine the length of the stride. Estimation of stride length can use static and dynamic approaches [30][33][34]. One of the popular models for estimating stride length is the Weinberg model [35], which is defined using Eq. (5).

$$Step\_Length = k \times \sqrt[4]{a_{max} + a_{min}} \quad (5)$$

k is a constant, while a_{max} dan a_{min} are the minima and maximum values of acceleration. Ho et al. [34], dynamically calculate k using Eq. (6), where $\bar{\upsilon}_{step}$ is the average velocity magnitude on the accelerometer sensor's x, y, and z axes at each step. To calculate $\bar{\upsilon}_{step}$ using equations (7), (8), (9), and (10).

$$k = 0.68 - 0.37 \times \bar{\upsilon}_{step} + 0.15 \times \bar{\upsilon}^2{}_{step} \quad (6)$$

$$\bar{\upsilon}_{step} = \sqrt{(\bar{\upsilon}_{stepX})^2 + (\bar{\upsilon}_{stepY})^2 + (\bar{\upsilon}_{stepZ})^2} \quad (7)$$

Chronologically, $\bar{\upsilon}_{stepX}$, $\bar{\upsilon}_{stepY}$, dan $\bar{\upsilon}_{stepZ}$ are the average velocity on the x, y, and z axes with a sampling point length of 30. The current velocity value is updated using the previous velocity value, while the time interval is obtained from 1 divided by the sampling rate sensor, which is 60 Hz.

$$\bar{\upsilon}_{stepX} = \frac{1}{30} \sum_{i=1}^{30} \left(\bar{\upsilon}_{stepX}(i-1) + (Ax_{fil}(\mathrm{i}) \times \frac{1}{60}) \right) \quad (8)$$

$$\bar{\upsilon}_{stepY} = \frac{1}{30} \sum_{i=1}^{30} \left(\bar{\upsilon}_{stepY}(i-1) + (Ay_{fil}(\mathrm{i}) \times \frac{1}{60}) \right) \quad (9)$$

$$\bar{\upsilon}_{stepZ} = \frac{1}{30} \sum_{i=1}^{30} \left(\bar{\upsilon}_{stepZ}(i-1) + (Az_{fil}(\mathrm{i}) \times \frac{1}{60}) \right) \quad (10)$$

Furthermore, using the Weinberg model, the k_{step} value is used to calculate the step length (L) so that equation (5) is rewritten into equation (11). Where max(SVMfil) and min(SVMfil) respectively, are the maximum and minimum values of SVM_{fil} that are found throughout 30 sampling points.

$$L = k_{step} \times \sqrt[4]{\max(SVM_{fil}) + \min(SVM_{fil})} \quad (11)$$

Identify applicable funding agency here. If none, delete this text box.

E. Position Estimation

The user's position in the room is presented on a smartphone screen display as a two-dimensional floor plan. Thus, a comparison scale is needed between the actual room size and a two-dimensional room plan. The displacement in one footstep will be represented by the displacement of the point in several pixels on the smartphone screen; the displacement of the point follows the coordinate system on the smartphone screen. The displacement is calculated using equations 12 and 13.

$$S_x = \mathrm{L} \times \frac{l_m}{l_r} \quad (12)$$

$$S_y = \mathrm{L} \times \frac{p_m}{p_r} \quad (13)$$

S_x and S_y are the value of point displacement in pixels on the x and y axes of the smartphone screen. While l_m and p_m are the length and width of a two-dimensional plan that represents the shape of the room in pixel size. For l_r and p_r are the length and width of the room. S_x and S_y are calculated if footsteps are detected. As shown in TABLE I, S_x and S_y are used to update the current positions of x and y, while x_0 and y_0 are the previous positions.

TABLE I. UPDATE POSITION IN FLOOR MAPS SMARTPHONE

No	Azimuth (α)	Current position
1	$0 \leq \alpha \leq 45$ and $315 \leq \alpha \leq 359$	$x=x_0$, $y=y_0 + Sy$
2	$45 < \alpha < 135$	$x= x_0 - S_x$, $y= y_0$
3	$135 \leq \alpha < 225$	$x= x_0$, $y= y_0 - Sy$
4	$225 \leq \alpha \leq 315$	$x= x_0 + S_x$, $y=y_0$

III. RESULT AND DISCUSION

The smartphone Model M1804C3DG is used as the test device. Its device has an Octa-Core Max 2.00 GHz processor, a screen size of 720 x 1440 pixels, and an accelerometer sampling rate of 60 Hz. Participants use the same device to perform the test scenarios.

A. Map of Building

The building presented in map form does not point to the north exactly but has an angle difference of 8°, as shown in Fig. 5. So before the movement value is updated, the angle in Table 1 is reduced by 8° using equation (14).

$$\alpha = \alpha - 8^o \quad (14)$$

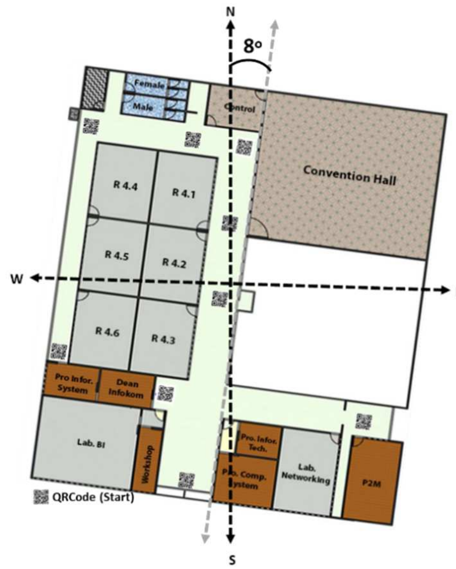

Fig. 5. Floor plans

Pedestrian navigation using the PDR technique requires a reference point as the initial position. In this study, to determine the starting position, smartphone users must scan a QRcode. The QRcode contains information on the position of the x and y-axis maps which are presented in the smartphone application. The QRcode label is placed in an easy-to-reach position and is the first point found by users visiting the building, for example, the exit/entrance of elevators and stairs.

B. Footstep Detection Test

The technique used to detect footsteps was performed on two participants, one male and one female, with a profile as shown in Table 2. Each participant took 7 test scenarios with a total of 280 steps. Each scenario takes a different number of steps, as shown in Table 3.

TABLE II. PARTICIPANT PROFILE

Participant	Gender	Height (cm)	Weight (kg)
1	Male	170	70
2	Famale	150	50

TABLE III. PARTICIPANT TEST

No.	Atcual Step	Detected steps	
		Participant 1	*Participant 2*
1	5	6	6
2	10	9	11
3	15	17	17
4	25	26	28
5	50	53	60
6	75	80	83
7	100	97	110

$$\%\, error = \frac{|actual\ step - detected\ step|}{actual\ step}\ x\ 100\% \quad (15)$$

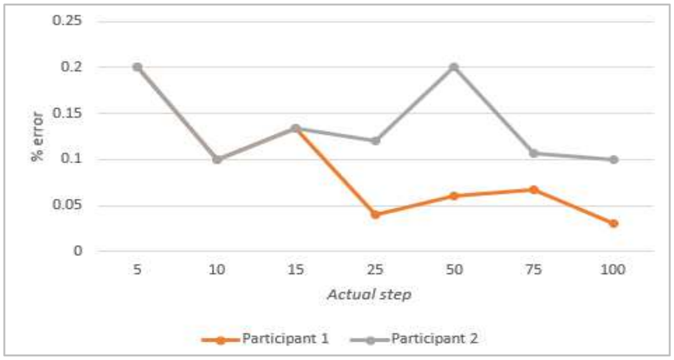

Fig. 6. Error percentage

The error percentage of each test scenario is calculated using equation (15). Fig 6 shows the percentage of errors decreases when the number of steps increases. This is probably due to the pattern of steps at the beginning of the walking; the acceleration value is irregular.

C. Floor plans of the test.

The initial position is known based on the QRcode installed at a certain point in the room (Fig. 7(a)). The smartphone is held while maintaining a tilt angle of 15 to 40 degrees, as shown in Fig. 7(b). For the user to know the tilt angle, the application presents the tilt angle of the smartphone held by the user, as shown in Fig. 8

(a) Scan initial position (b) Smartphone was placed in the hand

Fig. 7. Experimental Scenario

Fig. 8 App shows position and tilt angle

The test line is made by drawing a straight line from the Qrcode point to the next QRcode; then, the line is used as a reference point for the test plan path. Fig. 9 shows the results of the test position and the test plan. The green dotted line indicates the actual position path, while the red dotted line represents the planned path. When testing, the subject moves from the origin (o) to destination (d) through a planned path.

(a) Path testing 1 (b) Path testing 2

(c) Path testing 3 (d) Path testing 4

Fig. 9. Path testing and results

Four test paths have been carried out; the first test path has a length of 74.5 m, the second test path has a length of 59.7 m, and the third test path has a length of 32.5 m, while the fourth test track has a length of 48.5 m. The test results are calculated using equation (16), $x_{planned}$ and $y_{planned}$ are the positions on the planned x and y coordinates. While $x_{estimated}$ and $y_{estimated}$ are the positions of the estimated results on the x, and y coordinates, respectively. These x and y are the coordinate systems on the smartphone screen.

$$error(i) = \sqrt{\left|x_{planned(i)} - x_{estimated(i)}\right| + \left|y_{planned(i)} - y_{estimated(i)}\right|} \tag{16}$$

The error on each test path is shown in TABLE IV. Fig 10 shows that when the path length is shorter, there is a tendency for error to be greater than when the path is longer. It may be affected by the irregularity of the acceleration value when starting the footstep.

TABLE IV. PATH TESTING RESULTS

Path	Error
1	7.07
2	17.94
3	22.29
4	27.82

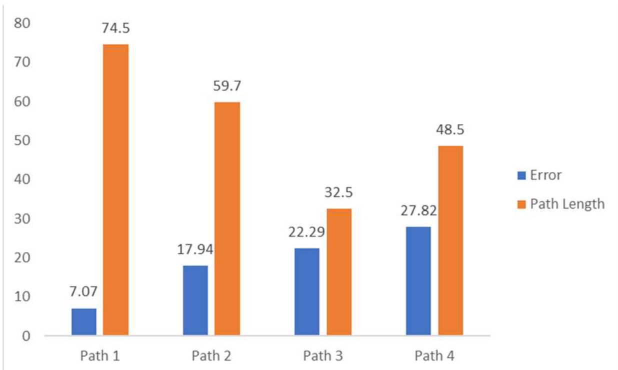

Fig. 10. Error and path length

IV. CONCLUSIONS

The initial position is identified from the information contained in the QRCode. When the smartphone is used to estimate the indoor positioning, the tilt angle is maintained at 15 to 40 degrees. The length of the sampling point from the acceleration of the accelerometer sensor is evaluated to calculate a step of 30 sampling points or half of the sensor's sampling rate. To determine whether the occurrence of a step or not is based on a threshold value. The test is carried out by calculating the error of the position estimation. The test results show that the longer path length produces a smaller error than the shorter path.

This study uses the maximum and minimum threshold values statically to detect the occurrence of steps and only detect forward steps. Using threshold values dynamically and detecting backward steps can be potential for future work.

REFERENCES

[1] S. Haykin, "Cognitive radio: brain-empowered wireless communications," *IEEE J. Sel. Areas Commun.*, vol. 23, no. 2, pp. 201–220, Feb. 2005.

[2] Xin-Yu Lin, Te-Wei Ho, Cheng-Chung Fang, Zui-Shen Yen, Bey-Jing Yang, and Feipei Lai, "A mobile indoor positioning system based on iBeacon technology," in *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2015, pp. 4970–4973.

[3] R. F. Brena, J. P. García-Vázquez, C. E. Galván-Tejada, D. Muñoz-Rodriguez, C. Vargas-Rosales, and J. Fangmeyer, "Evolution of Indoor Positioning Technologies: A Survey," *J. Sensors*, vol. 2017, pp. 1–21, Mar. 2017.

[4] X. Gan, B. Yu, Z. Heng, L. Huang, and Y. Li, "Indoor combination positioning technology of Pseudolites and PDR," in *2018 Ubiquitous Positioning, Indoor Navigation and Location-Based Services (UPINLBS)*, 2018, pp. 1–7.

[5] L. Yu, Y. Liu, T. Chi, and L. Peng, "An iBeacon-based indoor and outdoor positioning system for the fire emergency command," in *2017 Forum on Cooperative Positioning and Service (CPGPS)*, 2017, pp. 326–329.

[6] Z. Li and J. Huang, "Study on the use of Q-R codes as landmarks for indoor positioning: Preliminary results," in *2018 IEEE/ION Position, Location and Navigation Symposium (PLANS)*, 2018, pp. 1270–1276.

[7] J. Paek, J. Ko, and H. Shin, "A Measurement Study of BLE iBeacon and Geometric Adjustment Scheme for Indoor Location-Based Mobile Applications," *Mob. Inf. Syst.*, vol. 2016, pp. 1–13, Oct. 2016.

[8] W. Shao *et al.*, "Location Fingerprint Extraction for Magnetic Field Magnitude Based Indoor Positioning," *J. Sensors*, vol. 2016, pp. 1–16, Dec. 2016.

[9] G. Feng, L. Ma, and X. Tan, "Visual Map Construction Using RGB-D Sensors for Image-Based Localization in Indoor Environments," *J. Sensors*, vol. 2017, pp. 1–18, Oct. 2017.

[10] E. M. Gorostiza, J. L. Lázaro Galilea, F. J. Meca Meca, D. Salido Monzú, F. Espinosa Zapata, and L. Pallarés Puerto, "Infrared Sensor System for Mobile-Robot Positioning in Intelligent Spaces," *Sensors*, vol. 11, no. 5, pp. 5416–5438, May 2011.

[11] K. Y. Yi, D. Y. Kim, and K. M. Yi, "Development of a Localization System Based on VLC Technique for an Indoor Environment," *J. Electr. Eng. Technol.*, vol. 10, no. 1, pp. 436–442, Jan. 2015.

[12] A. De Angelis *et al.*, "Design and characterization of an ultrasonic indoor positioning technique," in *2014 IEEE International Instrumentation and Measurement Technology Conference (I2MTC) Proceedings*, 2014, pp. 1623–1628.

[13] Z.-A. Deng, Z. Qu, C. Hou, W. Si, and C. Zhang, "WiFi Positioning Based on User Orientation Estimation and Smartphone Carrying Position Recognition," *Wirel. Commun. Mob. Comput.*, vol. 2018, pp. 1–11, Sep. 2018.

[14] P. Kriz, F. Maly, and T. Kozel, "Improving Indoor Localization Using Bluetooth Low Energy Beacons," *Mob. Inf. Syst.*, vol. 2016, pp. 1–11, Apr. 2016.

[15] Z. Dong, C. Mengjiao, and L. Wenjuan, "Implementation of indoor fingerprint positioning based on ZigBee," in *2017 29th Chinese Control And Decision Conference (CCDC)*, 2017, pp. 2654–2659.

[16] H. Kong and B. Yu, "A Moving Object Indoor Tracking Model Based on Semiactive RFID," *Math. Probl. Eng.*, vol. 2018, pp. 1–7, Dec. 2018.

[17] D. Pham and Y. Suh, "Pedestrian Navigation Using Foot-Mounted Inertial Sensor and LIDAR," *Sensors*, vol. 16, no. 1, p. 120, Jan. 2016.

[18] S. Kaiser and C. Lang, "Detecting elevators and escalators in 3D pedestrian indoor navigation," in *2016 International Conference on Indoor Positioning and Indoor Navigation, IPIN 2016*, 2016.

[19] Z. Deng, X. Liu, Z. Qu, C. Hou, and W. Si, "Robust Heading Estimation for Indoor Pedestrian Navigation Using Unconstrained Smartphones," 2018.

[20] P. Zhang, Q. Zhao, Y. Li, X. Niu, Y. Zhuang, and J. Liu, "Collaborative WiFi Fingerprinting Using Sensor-Based Navigation on Smartphones," *Sensors*, vol. 15, no. 7, pp. 17534–17557, Jul. 2015.

[21] Z. Xiao, H. Wen, A. Markham, and N. Trigoni, "Robust indoor positioning with lifelong learning," *IEEE J. Sel. Areas Commun.*, vol. 33, no. 11, pp. 2287–2301, Nov. 2015.

[22] M. Zhou, Y. Tang, W. Nie, L. Xie, and X. Yang, "GrassMA: Graph-Based Semi-Supervised Manifold alignment for Indoor WLAN Localization," *IEEE Sens. J.*, vol. 17, no. 21, pp. 7086–7095, Nov. 2017.

[23] Y. Guo, Q. Liu, X. Ji, S. Wang, M. Feng, and Y. Sun, "Multimode Pedestrian Dead Reckoning Gait Detection Algorithm Based on Identification of Pedestrian Phone Carrying Position," 2019.

[24] J. Geng, L. Xia, J. Xia, Q. Li, H. Zhu, and Y. Cai, "Smartphone-Based Pedestrian Dead Reckoning for 3D Indoor Positioning," *Sensors (Basel).*, vol. 21, no. 24, Dec. 2021.

[25] Y. Liu, Q. Gong, S. Wang, L. Zhang, and F. Xu, "An Outdoor Pedestrian Localization Scheme Fusing PDR and VPR," *Wirel. Commun. Mob. Comput.*, vol. 2022, pp. 1–12, Aug. 2022.

[26] M. Martínez del Horno, L. Orozco-Barbosa, and I. García-Varea, "A smartphone-based multimodal indoor tracking system," *Inf. Fusion*, vol. 76, pp. 36–45, Dec. 2021.

[27] K. Yan, R. Chen, G. Guo, and L. Chen, "Locating Smartphone Indoors by Using Tightly Coupling Bluetooth Ranging and Accelerometer Measurements," *Remote Sens. 2022, Vol. 14, Page 3468*, vol. 14, no. 14, p. 3468, Jul. 2022.

[28] J. Zhu, W. Wang, S. Huang, and W. Ding, "An Improved Calibration

Technique for MEMS Accelerometer-Based Inclinometers," *Sensors 2020, Vol. 20, Page 452*, vol. 20, no. 2, p. 452, Jan. 2020.

[29] Q. T. Huynh, U. D. Nguyen, L. B. Irazabal, N. Ghassemian, and B. Q. Tran, "Optimization of an Accelerometer and Gyroscope-Based Fall Detection Algorithm," 2015.

[30] W. Lu, F. Wu, H. Zhu, and Y. Zhang, "A step length estimation model of coefficient self-determined based on peak-valley detection," *J. Sensors*, vol. 2020, 2020.

[31] Y.-C. Lai, C.-C. Chang, C.-M. Tsai, S.-C. Huang, and K.-W. Chiang, "A Knowledge-Based Step Length Estimation Method Based on Fuzzy Logic and Multi-Sensor Fusion Algorithms for a Pedestrian Dead Reckoning System," *ISPRS Int. J. Geo-Information 2016, Vol. 5, Page 70*, vol. 5, no. 5, p. 70, May 2016.

[32] A. Developer, "Motion sensors | Android Developers." [Online]. Available: https://developer.android.com/guide/topics/sensors/sensors_motion. [Accessed: 02-Jul-2021].

[33] A. Abadleh, E. Al-Hawari, E. Alkafaween, and H. Al-Sawalqah, "Step detection algorithm for accurate distance estimation using dynamic step length," in *Proceedings - 18th IEEE International Conference on Mobile Data Management, MDM 2017*, 2017, pp. 324–328.

[34] N. H. Ho, P. H. Truong, and G. M. Jeong, "Step-Detection and Adaptive Step-Length Estimation for Pedestrian Dead-Reckoning at Various Walking Speeds Using a Smartphone," *Sensors (Basel).*, vol. 16, no. 9, Sep. 2016.

[35] H. Weinberg, *Using the ADXL202 in Pedometer and Personal Navigation Applications*. Norwood, MA, USA,: Analog Devices, Inc., 2002.