II. Penjelasan bukti korespondensi, pertanyaan reviewer, dan revisi dari penulis

Judul artikel:

"Design and Evaluation of Upper-Arm Mouse using Inertial Sensor for Human-Computer Interaction"

Jurnal JESTEC (Journal of Engineering Science and Technology), menerapkan proses pengiriman naskah hingga seluruh proses korespondensi menggunakan Email ke jestec@taylors.edu.my

Adapun komunikasi dengan Editor dilakukan dengan Email, sebagai berikut:

1. Proses pengiriman naskah (1 Mei 2020)

Journal Paper Submission

Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Fri 5/1/2020 3:02 PM
To:Jestec <Jestec@taylors.edu.my>
Bcc:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>;romy_budhi <romy_budhi@yahoo.com>

6 attachments (6 MB)
Copyright transfer ver 190818 - Widodo.pdf; Curriculum_Vitae_romy01052020_english.pdf; JESTEC upper arm mouse20 (for Blind Review).docx; PPR Widodo.xlsx; similarity check-DESIGN AND EVALUATION OF UPPER ARM MOUSE FOR POINTING DEVICE (1).pdf; Proofread--EME Certificate 104475_Jestec April 2020_4_28_2020.pdf;

Dear Assoc. Prof. Dr. Abdulkareem S. Mahdi Al-Obaidi,
(The Executive Editor of JESTEC)

Good afternoon Professor,
Please find the enclosed documents containing the manuscript to the JESTEC with the title:

"Design and Evaluation of Upper Arm Mouse for Pointing Device"

We sincerely appreciate the helpful and support.
Thank you very much for facilitating this submission.

Sincerely,

Romy B. Widodo, A. Haryasena, Hendry Setiawan, and Chikamune Wada

2. Bukti penerimaan naskah dari Editorial (4 Mei 2020)

Your paper is received

Jestec <Jestec@taylors.edu.my>
Mon 5/4/2020 8:45 AM

Dear Author
Thank you for your interest to publish in our journal.
Please accept our apologies in replying your email.
We confirmed that we received your email.
We will check your submission and will reply you soon.
Thank you for your patience.
Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

3. Pemberitahuan proses review First-Round (4 Mei 2020)

Submission of a Manuscript (EE20139) / First Round of the Review Process

Jestec <Jestec@taylors.edu.my>
Mon 5/4/2020 10:21 AM
To:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Dear Author

Thank you for submitting your research paper to the Journal of Engineering Science and Technology (JESTEC)

Kindly note that we have received the paper entitled

DESIGN AND EVALUATION OF UPPER ARM MOUSE FOR POINTING DEVICE

Your paper ID is **EE20139** (*Please quote the above manuscript ID in all future correspondence with us.)*

Soon we will initiate the first round of the review process.

Please be reminded that upon the full acceptance of your paper, publication fee in amount of USD300 must be paid before the article is published in the journal website.

Best regards

JESTEC Editor
http://jestec.taylors.edu.my

4. Pemberitahuan hasil review first round, dilampiri *reviewers' comment* (26 Juli 2020)

Paper ID EE20139 /Review of a paper, First Round Result/

Jestec <Jestec@taylors.edu.my>
Sun 7/26/2020 11:01 PM
To:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>

5 attachments (252 KB)
outlining of Review Report_v3.docx; Review Report - 1.docx; Review Report - 2.docx; Review Report - 3.docx; Review Report - 4.docx;

Dear Author

The first round of the review process has been completed.

I am glad to advise that your paper has been conditionally accepted for publication with

☐ No modification ☑ Minor corrections ☑ Major modification.

Attached herewith, please find

☐ 1 ☐ 2 ☐ 3 ☑ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 reviewers' reports.

Please notice the following:

1. Address all the concerns/recommendations of the reviewers
2. All amendments made are to be highlighted in red color in the revised paper.
3. Send an outlining following the instructions in the attached file on how did you address each reviewers' concern/recommendations.
4. In order to complete the review process on time, we highly appreciate it if we can receive the revised paper within **three weeks** from today.
5. Please take note that your revised manuscript may be rejected if the corrections and the revision are not satisfactory.
6. In case that you will need more time to complete the revision, please indicate how much time you need via an email so we can get the approval from the Editorial Board.

Please note that the final acceptance of the paper depends on the final decision of the Review Panel and after the paper successfully passed all the review rounds.

Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

5. Permohonan penambahan waktu masa revisi dari penulis (5 Agustus 2020)

Re: Paper ID EE20139 /Review of a paper, First Round Result/

Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Wed 8/5/2020 3:04 PM
To:Jestec <Jestec@taylors.edu.my>

Dear Jestec Editorial,

Thank you for the comment from reviewers on our paper EE20139.
As already two weeks elapsed, I have revised some parts of the reviewer's comments. However, would you give me more time to revise the paper, please.
I need one week more than the schedule.

Thank you for your attention and support.

Sincerely yours,

Romy Budhi

From: Jestec <Jestec@taylors.edu.my>
Sent: Sunday, July 26, 2020 11:00 PM
To: Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Subject: Paper ID EE20139 /Review of a paper, First Round Result/

6. Pengiriman hasil revisi naskah dan bukti penerimaan dari Editorial (12 Agustus 2020)

EE20139-Revision Submission-Re: Paper ID EE20139 /Review of a paper, First Round Result/

Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Wed 8/12/2020 9:38 AM
To:Jestec <Jestec@taylors.edu.my>

4 attachments (4 MB)
outlining of Review Report_v3-EE20139.pdf; outlining of Review Report_v3-EE20139.docx; JESTEC upper arm mouse35_final-revised.pdf; JESTEC upper arm mouse35_final-revised.docx;

Dear JESTEC Editor,

Thank you for the opportunity to give a chance to revise the paper EE20139.
Please receive our revised paper in the first round revision and outlining review report files.

Thank you for your kind attention and support. I forward to hearing from you.

Sincerely yours,
Author,
Romy Budhi

RE: EE20139-Revision Submission-Re: Paper ID EE20139 /Review of a paper, First Round Result/

Jestec <Jestec@taylors.edu.my>
Wed 8/12/2020 11:04 PM
To:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>

Dear Author

Thank you for your email.
We confirmed that we received your email.
We will check your submission and will reply you soon.
Thank you for your patience.

Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

7. Pemberitahuan masuk *2nd round-review process* (22 Agustus 2020)

FW: Paper ID EE20139 /A progress of Review Process/

Jestec <Jestec@taylors.edu.my>
Sat 8/22/2020 4:43 PM
To:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>

Dear Author

This email is to confirm that your paper is currently undergoing the

☐ 1st ☑ 2nd ☐ 3rd round of the review process.

Thank you for your patience.

Best regards

JESTEC Editor
http://jestec.taylors.edu.my

8. Pemberitahuan masa tunggu (8 September 2020)

Review Status of a paper (EE20139)

Jestec <Jestec@taylors.edu.my>
Tue 9/8/2020 8:10 PM
To:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>

Dear Author

The review of your paper has been not completed yet. Up to this moment we do not have adequate numbers of review reports to share.
We are planning to send you the result of the review process before or latest by 20/9/2020.
Thank you for your patience.

Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

9. Pemberitahuan **Accepted Paper,** permintaan Copyright transfer, dan perbaikan format sitasi. (9 September 2020)

Paper ID (EE20139) Review process is completed

Jestec <Jestec@taylors.edu.my>
Wed 9/9/2020 7:42 PM
To:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>

2 attachments (234 KB)
JESTEC template (Camera Ready)_new.docx; about formatting the references.docx;

Dear Author

I am glad to advise that your paper has been accepted for publication without modification. The reviewers have no more comments and they are satisfied with the revised paper.

By this the review process is completed and we kindly ask you to check the format of the paper according to the instructions for authors and JESTEC template (attached).

Special attention to be paid for list of symbols used and the references. Please follow strictly the instructions for citation of the references (attached are instructions) and explain each symbol you used and its SI units. Also refer to this link:
http://jestec.taylors.edu.my/instructions.html

You are also kindly required to fill in the JESTEC-Copyright transfer form (use this link to download http://jestec.taylors.edu.my/Copyright%20transfer%20ver%20190818.doc and send to the journal.

Kindly note that you have only four weeks to submit the above.

Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

10. Balasan email ke Editor untuk **pengiriman Camera Ready Paper dan Copyright Transfer form**. (10 September 2020)

Re: Paper ID (EE20139) Review process is completed

Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Thu 9/10/2020 11:42 PM
To: Jestec <Jestec@taylors.edu.my>

3 attachments (4 MB)
Copyright transfer ver 190818 - EE20139.pdf; JESTEC EE20139 (Camera Ready)_new.docx; JESTEC EE20139 (Camera Ready)_new.pdf;

Dear Executive Editor of JESTEC,

I am very thankful for the completed process of review of our paper EE20139.
We have formatted the camera ready paper (attached) as the instructions, include the revision of citation.
Please accept the camera ready paper and the copyright transfer document.

Thank you for your cooperation and support, we looking forward to hearing from you.

Sincerely yours,
Author,

Romy Budhi

From: Jestec <Jestec@taylors.edu.my>
Sent: Wednesday, September 9, 2020 7:42 PM
To: Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Subject: Paper ID (EE20139) Review process is completed

11. Permintaan publication fee/pengiriman invoice dari Editor (29 September 2020)

Publication Fees for publication in a regular issue in JESTEC 2020 - Invoice No. 3098/20 of RM 1320.00 (Ref. No. 20_153)

Jestec <Jestec@taylors.edu.my>
Tue 9/29/2020 12:30 PM
To:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Cc:Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>

1 attachments (46 KB)
20_153 IN000003098.pdf;

Dear Author,

Greetings

Please refer to the attached invoice and do update us once the payment is made.

Please take note of the following:

- The only payment method is via Telegraphic Transfer (outside Malaysia) or Online Transfer (inside Malaysia).
- Banking details are provided in the invoice that will be sent to you.
- You have option to pay either in USD or RM.
- In either case the net amount to be received is exactly as stated in the invoice.
- The journal will not accept any bank charges associated with the transfer of money or currency exchange charges. Authors should bear all these service charges.

Thank you.

Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

12. Balasan penulis: pengiriman bukti transfer publication fee (1 Oktober 2020)

Re: Publication Fees for publication in a regular issue in JESTEC 2020 - Invoice No. 3098/20 of RM 1320.00 (Ref. No. 20_153)

Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>
Thu 10/1/2020 10:30 AM
To:Jestec <Jestec@taylors.edu.my>

1 attachments (1 MB)
payment for invoice IN000003098-paper EE20139.jpg;

Dear The Editor of Jestec,
(the Accounting Division)

Thank you for the invoice. Today, we have sent the payment as indicated by using USD. (USD 300). Please receive our bank notes for the paper EE20139.
Author: Romy Budhi Widodo, et.al.

aplikasi setoran/transfer/kliring/inkaso
deposit/transfer/clearing/collection form

mandiri

kepada PT Bank Mandiri (Persero) Tbk — tanggal 1-Oct 2020

harap dilakukan transaksi berikut

transaksi: setoran ☐ TT ☐ RTGS ☐ SKNBI ☐ Kliring inkaso ☐ Bank draft ☐

harap ditulis dengan huruf cetak *please fill in with block letters*

VALIDASI

PENERIMA (wajib diisi)
Status kependudukan
Nama: Taylor's University SDN BHD
Nomor rekening: OCBC Bank (Malaysia) Berhad
Bank: 701-130855-6
Alamat & telp penerima: SWIFT : OCBCMYKLXXX
Jenis & Nomor Identitas

perorangan ☐ penusahaan ☑ pemerintah ☐
penduduk ☐ bukan penduduk ☐

TUJUAN TRANSAKSI: Tabungan / investasi ☐ Pembayaran ☑ Biaya hidup ☐ Bisnis ☐ Pembelian barang / jasa ☐ Donasi / amal ☐
BERITA TRANSAKSI: INVOICE 3098/20

diisi oleh Bank *filled out by the Bank*

Jumlah transfer	
Komisi	
Biaya Pengiriman (SWIFT/RTGS/SKNBI)	
Biaya Koresponden	
Sub Total	
Kurs	
Total	

PT. BANK MANDIRI

Informasi pengirim: perorangan ☑
Status kependudukan: penduduk ☐
Nama: Romy Budhi
Alamat & nomor telepon: 081136 0105 Jl. [illegible]

METODE TRANSAKSI (wajib diisi)
tunai ☐ debet rekening ☑ 1440013873481

Bank Tertarik	No. cek/BG	Valuta	Nominal
		US $	300

Jumlah setoran/transfer/kliring/inkaso
Terbilang: Tiga ratus US dollar

SUMBER DANA TRANSAKSI (wajib diisi)
Gaji / penghasilan ☐ Tabungan / hasil investasi ☑ Warisan ☐
Hibah / hadiah ☐ Penjualan aset ☐ Hasil usaha ☐

BIAYA TRANSAKSI
Tunai ☐ Debet rekening: ☐
Biaya bank koresponden: Pengirim ☐ Penerima ☐ Lainnya ☐

2020

Thank you for your support. We are looking forward to hearing from you.

Sincerely yours,
Romy Budhi Widodo

13. Pemberitahuan Paper akan Publish pada Volume 6, Des 2020 (tgl email: 29 Nov 2020)

RE: Your paper to publish in Volume 15 Issue 6/confirmation/

Jestec <Jestec@taylors.edu.my>
Mon 11/30/2020 7:31 AM

Dear Authors
Thank you for the confirmation.
You may expect an email to correct your papers if issues are found.
Meanwhile your paper titles will appear online soon but the content remains inaccessible until we finalise the camera-ready of the online version of your papers.
Thank you for your patience
Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

From: Jestec
Sent: Sunday, November 29, 2020 3:33 PM
To: Ali Jasim Ramadhan Alaameri' <ali.j.r@ieee.org>; Ahmed Majeed <40349@uotechnology.edu.iq>; akeel aldayni <akeel19722004@yahoo.com>; Dr. BASIM AL-OBAIDI <dr.basimal-obaidy@coeng.uobaghdad.edu.iq>; Abbas Al Jasani <abbasaljassani@uowasit.edu.iq>; Harini Sosiati <hsosiati@ft.umy.ac.id>; Akmal JR <mizieusm@gmail.com>; Mhalsakant Sardeshmukh <mmsardeshmukh2016@gmail.com>; Zahraa Talal <zahraatalal84@gmail.com>; muna taher <muna.taher@gmail.com>; ali khalil <ali.alrifaie@mu.edu.iq>; Dr.Eng. Romy Budhi Widodo <romy.budhi@machung.ac.id>; wahda Al-Hinkawi <wahdahankawi@gmail.com>; aishah salleh <sitinoraishah.salleh@gmail.com>; ali sarairah <alisarairah@hotmail.com>; Erwin Sutanto <erwin_sutanto@fst.unair.ac.id>; Adnan Jabir <adnanjjabir@gmail.com>; Iman Majid <imanameer2015@gmail.com>; Saad Jabar Al-Wazni . <saad.alwazni@uokufa.edu.iq>; Navya Mohan (ECE <m_navya@cb.amrita.edu>; Suniti Suparp <suniti@g.swu.ac.th>; girishcr1@rediffmail.com; Bambang Iskandriawan <iskandriawan100@gmail.com>; akincitc@itu.edu.tr; keerthi Nandakumar <keerthi13.vj@gmail.com>; Ameer Jaddoa <Ameer.A.Jaddoa@uotechnology.edu.iq>; bilal naji <bilalnaji11@yahoo.com>; KHOO VOON CHING ERS182003 <vckhoo@graduate.utm.my>; Asep Bayu Dani Nandiyanto <nandiyanto@upi.edu>; oubeytaha@hotmail.com; mhmdaldbag@yahoo.com; tommi.hariyadi@upi.edu; arief_s@amikom.ac.id
Subject: Your paper to publish in Volume 15 Issue 6/confirmation/
Importance: High

Dear Author(s)

Your paper is scheduled to be published in the coming issue, **Issue 6, Volume 15, December 2020.**

Currently, we are editing your paper to prepare and later upload it online in **December 2020**.

This email is to inform you and also to get your confirmation that you agree to publish your paper.

Also, to kindly request you to stay stand by in case we find any mistakes which may require your immediate action.

Please reply before or latest by **1/12/2020.**

In case of no reply from you by the above-stated date, the publication of your paper will be postponed to **Volume 16 Issue 2 April 2021.**

Thank you for your immediate reply and cooperation.

Best Regards

JESTEC Editor
http://jestec.taylors.edu.my

Komentar/Pertanyaan Reviewers:

Reviewer 1:

Journal of Engineering Science and Technology (JESTEC)

REVIEW FORM

Title of paper: Design and evaluation of upper arm mouse for pointing device
(New title: Design and Evaluation of Upper Arm Mouse Using Inertial Sensor for Human Computer Interaction)

For sections A & B, please tick a number from 0 to 5, where 0 = strongly disagree and 5 = strongly agree.

A. Technical aspects

1. The paper is within the scope of the Journal.	☐ 0	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5
2. The paper is original.	☐ 0	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5
3. The paper is free of technical errors.	☐ 0	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5

B. Communications aspects

1. The paper is clearly readable.	☐ 0	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5
2. The figures are clear & do clearly convey the intended message.	☐ 0	☐ 1	☐ 2	☑ 3	☐ 4	☐ 5
3. The length of the paper is appropriate.	☐ 0	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5

C. Comments to the authors (You may use another sheet of paper.)

The author should review the work related to the research of this article!
The content of design and manufacture of this device has not been clearly seen in the article!
Note that the author cites the document when reusing the formula
The reviewer has not yet presented the hardware design for the device, nor the device's software program algorithm
This study is like a report of the device testing results
The introduction and conclusion should be written down to clarify the content of research and the achieved results
There are spelling errors in article manuscripts

D. Recommendation (Tick one)

1. Accepted without modifications.	☐
2. Accepted with minor corrections.	☐
3. Accepted with major modification.	☑
4. Rejected.	☐

E. Comments to the editors (These comments will not be sent to the authors)

This study is like a report of the device testing results
If this is a scientific work, it is necessary to have a review of relevant published studies, and write additional content on the hardware design and software of the device.

Page 1 of 1

Reviewer 2:

Journal of Engineering Science and Technology (JESTEC)

REVIEW FORM

Title of paper: DESIGN AND EVALUATION OF UPPER ARM MOUSE FOR POINTING DEVICE
(New title: Design and Evaluation of Upper Arm Mouse Using Inertial Sensor for Human Computer Interaction)

For sections A & B, please tick a number from 0 to 5, where 0 = strongly disagree and 5 = strongly agree.

A. Technical aspects

1. The paper is within the scope of the Journal.	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☑ 5
2. The paper is original.	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☑ 5
3. The paper is free of technical errors.	☐ 0	☐ 1	☐ 2	☐ 3	☑ 4	☐ 5

B. Communications aspects

1. The paper is clearly readable.	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☑ 5
2. The figures are clear & do clearly convey the intended message.	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☑ 5
3. The length of the paper is appropriate.	☐ 0	☐ 1	☐ 2	☐ 3	☐ 4	☑ 5

C. Comments to the authors (You may use another sheet of paper.)

In part 2.5 Experiment Design, the author mentioned "within-subject design" (it is a dependent case). However, the statistical method in part 3.1 using independent case (Kruskall Wallis and Mann Whitney test), please change to dependent case, such as, Friedman test and Wilcoxon Signed-rank.

D. Recommendation (Tick one)

1. Accepted without modifications.	☐
2. Accepted with minor corrections.	☑
3. Accepted with major modification.	☐
4. Rejected.	☐

E. Comments to the editors (These comments will not be sent to the authors)

Page 1 of 1

Reviewer 3:

REVIEW FORM

Title of paper: Design and Evaluation of Upper Arm Mouse Using Inertial Sensor for Human Computer Interaction

For sections A & B, please tick a number from 0 to 5, where 0 = strongly disagree and 5 = strongly agree.

A. Technical aspects

1. The paper is within the scope of the Journal.	☐ 0	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5
2. The paper is original.	☐ 0	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
3. The paper is free of technical errors.	☐ 0	☑ 1	☐ 2	☐ 3	☐ 4	☐ 5

B. Communications aspects

1. The paper is clearly readable.	☐ 0	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
2. The figures are clear & do clearly convey the intended message.	☐ 0	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5
3. The length of the paper is appropriate.	☐ 0	☐ 1	☑ 2	☐ 3	☐ 4	☐ 5

C. Comments to the authors (You may use another sheet of paper.)

1) Title of the research paper must be revises to reflect sensor technology as reflected in simulation using Adriano sensor board.
2) Author Should add some background study.
3) Motivation should be added in introduction section; why this research has been conducted.
4) Authors should add research contribution / Achievement in the last paragraph of introduction section.
5) No related work section has been added to reflect the existing studies done in this domain with their limitation and drawbacks.
6) Section 2.1 Experiment design should be renamed as Experimental Scenario
7) Experimental results added in table 2 ,3 and 4 should also be presented in figures to reflect (Error rate, Throughput and Mean Results).
8) Title of section 3.3 Research Results: People with Disabilities should be revised it should be with some attractive heading; Application or Implementation Domains etc
9) If possible so add some flowchart or algorithm that best describe working of your research methodology.
10) Author should add some relevant latest existing studies in the related work section as guided earlier and further results should also be compared with those research already conducted in this domain so that major contribution of your research work could be analyzed bitterly.
11) Conclusion should not be represented in bullets or points so it should be rewrite and these points must be adjusted in some other section.

12) Author should improve write-up in terms of grammatical mistakes and a proof read is required.

13) Reference needs to be improved as no citation of good journal or conference paper has been found from the last 3 years only some url been cited in this regards. Authors are advised to add more latest citation from last 3 to 5 years.

D. Recommendation (Tick one)

1. Accepted without modifications.	☐
2. Accepted with minor corrections.	☐
3. Accepted with major modification.	☑
4. Rejected.	☐

E. Comments to the editors (These comments will not be sent to the authors)

This paper lacks majorly in terms of methodology, Literature Review, Results and Analysis Discussion.

Reviewer 4:

Journal of Engineering Science and Technology (JESTEC)

REVIEW FORM

Title of paper: Design and Evaluation of Upper Arm Mouse For Pointing Device
(New title: Design and Evaluation of Upper Arm Mouse Using Inertial Sensor for Human Computer Interaction)

For sections A & B, please tick a number from 0 to 5, where 0 = strongly disagree and 5 = strongly agree.

A. Technical aspects

1. The paper is within the scope of the Journal.	☐ 0	☐ 1	☐ 2	☐ 3	√ 4	☐ 5
2. The paper is original.	☐ 0	☐ 1	☐ 2	☐ 3	√ 4	☐ 5
3. The paper is free of technical errors.	☐ 0	☐ 1	☐ 2	√ 3	☐ 4	☐ 5

B. Communications aspects

1. The paper is clearly readable.	☐ 0	☐ 1	☐ 2	☐ 3	√ 4	☐ 5
2. The figures are clear & do clearly convey the intended message.	☐ 0	☐ 1	☐ 2	☐ 3	√ 4	☐ 5
3. The length of the paper is appropriate.	☐ 0	☐ 1	☐ 2	☐ 3	√ 4	☐ 5

C. Comments to the authors (You may use another sheet of paper.)

1. What is the novelty of the paper?
2. There are so many word "We". Please replace these words with another word.
3. Introduction is not clear. What is the background of the paper? What the researchers have done previously in accordance with your paper? What have the authors done that different to the previous researchers ?
4. In page 3, line 13 second paragraph. The authors wrote "as shown in 10". What is the meaning of this sentence?
5. There are the incorrect ways to cite the references, like "with special needs 1", As can be seen in 2, etc.
6. In page 7, there is the empty space, please fill it.
7. Table 2, experimental results. These results are not clear. Did the author get these results manually or automatically?
8. Table 2. Are the experimental results good? It is better for the author to show a comparison with has been done by previous researchers. I hope there is international standard of the results, so the author can compare their results to international standard or another researcher.
9. What is the future work of the paper?

D. Recommendation (Tick one)

1. Accepted without modifications.	☐
2. Accepted with minor corrections.	☐
3. Accepted with major modification.	√

4. Rejected. ☐

E. Comments to the editors (These comments will not be sent to the authors)

Balasan Penulis berupa Outlining "*how the issues are addressed*"

Journal of Engineering Science and Technology (JESTEC)

OUTLINING HOW THE ISSUES ARE ADDRESSED

Title of paper: Design and Evaluation of Upper Arm Mouse for Pointing Device
(New title: Design and Evaluation of Upper Arm Mouse Using Inertial Sensor for Human-Computer Interaction)

1. Address all the concerns/recommendations of the reviewers.
2. All amendments made are to be highlighted in red color in the revised paper.

Reviewer # 1

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
• The author should review the work related to the research of this article	Y	Thank you for the suggestion. We have addressed this comment: 1. The new **section 1.2. Related Work** has been added. The sentence is "The use of arm movement to emulate the mouse cursor ….". The new references have been added. Also, the new figure (Fig. 1) added based on the works related study. 2. The first paragraph of **Discussion part:** The comparison of the works related research to the proposed study were elaborated in this paragraph.
• The content of design and manufacture of this device has not been clearly seen in the article	Y	1. The parts of the hardware design were explained in **part 2. Materials and Method**. It consists of IMU GY-951, Arduino Uno, HC-05 Bluetooth module, Bend sensor/flex sensor, and EMG MyoWare. 2. Figure 3 is the wiring diagram of the hardware manufacture. Since the researchers use off the shelf product such as: IMU GY-951, Arduino Uno, HC-05 Bluetooth module, Bend sensor/flex sensor, and EMG MyoWare; we did not

		design each module by ourselves. 3. The new figure was added. Figure 4 llustrates the software flowchart of the proposed system.
• Note that the author cites the document when reusing the formula	Y	The new sentence was added before equation (1). The sentence gives statement that equation (1) to (4) adapted from ISO/TS 9241-411 document. The statement is "The equations (1) to (4) are adapted from ISO/TS 9241-411 [15]" The new literature, literature number [17], was added for equation (5) and (6). The statement in the sentence is "Eqs. (5) and (6) adapted from [17] were implemented in the software"
• The reviewer has not yet presented the hardware design for the device, nor the device's software program algorithm	Y	Figure 4 has been added for software program of the proposed system. The hardware design has been declared in the Figure 2 and Figure 3.
• This study is like a report of the device testing results	Y	Thank you for your point. The research article in the field of "human-computer interaction" area comes from empirical research. The methodology of the research adapted from a HCI book of Prof. I. Scott MacKenzie (Yorku University, CA), the title is "Human-Computer Interaction: An Empirical Research Perspective" (http://dspace.utalca.cl/bitstream /1950/10513/1/I.scott_mackenzie.pdf) The paper is not device testing report but the result of the experiment based on the research methodology. The flow of this empirical research is: The background of the research, the design of hardware and software, the gold reference for testing (MTx Awinda), the ISO/TS 9241-411 as a standard testing procedure for a new pointing device, and finally we have been report the result based on statistical analysis.
• The introduction and conclusion should be written down	Y	- The new sentence of research

to clarify the content of research and the achieved results		content has been added on the last paragraph of **part 1.2. Related Work.** The last sentence is "Using the proposed system, the researchers would like to contribute by reducing the number of people with special needs who are unemployed and increase human welfare through new job opportunities using an upper-arm mouse that will be created" - The achieved results were added in **part Conclusions**: "The quantitative result shows that the throughput of device #1 is significantly higher than device #2 ($Z = -3.064$, $p = 0.002$). While the movement time also shows device #1 is faster than device #2, the differences of both devices are statistically significantly different ($Z = -3.059$, $p = 0.002$). The qualitative result was concluded from comfort and fatigue questionnaires. The result shows that the assessment of comfort for device #1 is significantly higher than device #2 ($Z = -4.56$, $p = .00$). However, the fatigue of device #1 and device #2 does not differ statistically, although device #1 shows slightly higher value"
• There are spelling errors in article manuscripts	Y	Thank you for your suggestion. The article has been checked by a native English speaker, and linguistic errors have been corrected. We include certificate of proofread in the link: **https://bit.ly/2EGAvBM**

(Please add more rows if needed)

Reviewer # 2

Final Recommendation Please tick	**Accepted without modification** ☐	**Accepted with minor corrections** ☐	**Accepted with major modification** ☐	**Rejected** ☐

Comments	**Addressed (Y/N)**	**Reply/Action taken**
• In part 2.5 Experiment Design, the author mentioned "within-subject design" (it is a dependent case). However, the statistical method in part 3.1 using independent case (Kruskall Wallis and Mann Whitney test), please change to dependent case, such as, Friedman test and Wilcoxon Signed-rank	Y	Thank you for your valuable suggestion. The article has been revised: 1. The last sentence in section 2.5 2. Part 3 (Experiment Result), the part 3.1 has been modified using the new statistical method. We also added the google drive

		shared document link of data. 3. Part 3.2 (qualitative result) has been modified using a new statistical result (Wilcoxon-signed rank test)
•		

(Please add more rows if needed)

Reviewer # 3

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
• Title of the research paper must be revises to reflect sensor technology as reflected in simulation using Adriano sensor board.	Y	Thank you for the suggestion, the previous title is: Design and evaluation of upper arm mouse for pointing device The revised title would be: Design and Evaluation of Upper Arm Mouse Using Inertial Sensor for Human-Computer Interaction
• Author Should add some background study	Y	The new section **part 1.1. Background** was **added.** Paragraph two and three consent to the background study.
• Motivation should be added in introduction section; why this research has been conducted	Y	Thank you for the suggestion, the new sentence was added in the paragraph two of **part 1.1. Background**. The sentence is "The number of unemployed people with special needs is the background of this study ...."
• Authors should add research contribution / Achievement in the last paragraph of introduction section	Y	The suggestion has been addressed. The sentence is "Using the proposed system, the researchers would like to contribute by reducing the number of people with special needs who are unemployed and increase human welfare through new job opportunities using an upper-arm mouse that will be created." in the last sentence of **part 1.2. Related Work.**

• No related work section has been added to reflect the existing studies done in this domain with their limitation and drawbacks	Y	The existing study has been added in the new part: **part 1.2. Related Work.**
• Section 2.5 Experiment design should be renamed as Experimental Scenario	Y	The suggestion has been addressed in **Section 2.5.**
• Experimental results added in table 2 ,3 and 4 should also be presented in figures to reflect (Error rate, Throughput and Mean Results).	Y	The suggestion has been addressed by adding: - Fig.9: Throughput and movement time graph. - Fig. 10: Error rate as a function of index of difficulty level. - Fig. 11: Result of qualitative from questionnaires' items.
• Title of section 3.3 Research Results: People with Disabilities should be revised it should be with some attractive heading; Application or Implementation Domains etc	Y	The suggestion has been addressed by revised the section title: **3.3 Special report on the device usage in an individual with a special need.**
• If possible so add some flowchart or algorithm that best describe working of your research methodology.	Y	The suggestion has been addressed. Figure 4 has been added for software program of the proposed system.
• Author should add some relevant latest existing studies in the related work section as guided earlier and further results should also be compared with those research already conducted in this domain so that major contribution of your research work could be analyzed bitterly.	Y	Thank you for the suggestion. The suggestion was addressed by adding **part 1.2. Related Work.** The comparison between the proposed study and the related work, discussed in the first paragraph of **part 4. Discussion**.
• Conclusion should not be represented in bullets or points so it should be rewrite and these points must be adjusted in some other section.	Y	The conclusion has been rewritten combined with the comment of Reviewer #1 (the 6th comment).
• Author should improve write-up in terms of grammatical mistakes and a proof read is required.	Y	Thank you for your suggestion. The article has been checked by a native English speaker, and linguistic errors have been corrected. We include certificate of proofread in the link: **https://bit.ly/2EGAvBM**
• Reference needs to be improved as no citation of good journal or conference paper has been found from the last 3 years only some url been cited in this regards. Authors are advised to add more latest citation from last 3 to 5 years	Y	The suggestion addressed by adding references [5], [19], and [21]

(Please add more rows if needed)

Reviewer # 4

Final Recommendation Please tick	Accepted without modification	Accepted with minor corrections	Accepted with major modification	Rejected
	☐	☐	☐	☐

Comments	Addressed (Y/N)	Reply/Action taken
• What is the novelty of the paper?	Y	Thank you for the comment and suggestion. The comment has been addressed by adding the novelty in the third paragraph of **part 1.2 Related Work.** "The novelty of the proposed device is on the placement of sensors (i.e., on the upper arm), the use of low-cost IMU, and a standard evaluation procedure using ISO/TS 9241-411. In this study, the gesture of the right upper arm movement would emulate the mouse cursor, and the clicking action comes from EMG or bend sensor."
• There are so many word "We". Please replace these words with another word.	Y	The suggestion has been addressed.
• Introduction is not clear. What is the background of the paper? What the researchers have done previously in accordance with your paper? What have the authors done that different to the previous researchers?	Y	- Thank you for the suggestion. We added a new part at **section 1.1. Background**. - The new section **1.2 Related Work** has been added. Some references have been added in this section.
• In page 3, line 13 second paragraph. The authors wrote "as shown in 10". What is the meaning of this sentence?	Y	I am sorry for the technically problem of word to pdf converter. The intended sentence means reference [10]. The problem solved.
• There are the incorrect ways to cite the references, like "with special needs 1", As can be seen in 2, etc.	Y	There were problems in our word to pdf converter. The problem solved.
• In page 7, there is the empty space, please fill it.	Y	The problem solved.
• Table 2, experimental results. These results are not clear. Did the author get these results manually or automatically?	Y	Thank you for your point. Table 2 is the result of offline data. We added Fig. 2 to illustrates the software flowchart. The movement of cursor based on real time data of IMU sensor and EMG/bend sensor. However, for experiment purposes, the option of collecting cursor coordinate into .csv file is available in the GUI. Therefore, from this .csv.

		file, we calculate the average as in Table 2.
• Table 2. Are the experimental results good? It is better for the author to show a comparison with has been done by previous researchers. I hope there is international standard of the results, so the author can compare their results to international standard or another researcher.	Y	The comparison to international standard is only for mouse. However, the comparison of the proposed Device #1 and Device #2 with other researchers is not available, since the other researcher did not use ISO9241-411 as a reference for testing measurement. The result of our mouse calculation is in the same with other researchers. It means that our experiment procedure and design were inline with others. The discussion of this is in the second paragraph of **part 4. Discussion**.
• What is the future work of the paper?	Y	The suggestion has been addressed by adding the future work in **part. Conclusion.**

(Please add more rows if needed)

Reviewer # 5

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 6

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 7

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 8

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 9

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed (Y/N)	Reply/Action taken
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Reviewer # 10

Final Recommendation Please tick	Accepted without modification ☐	Accepted with minor corrections ☐	Accepted with major modification ☐	Rejected ☐

Comments	Addressed	Reply/Action taken

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DESIGN AND EVALUATION OF UPPER-ARM MOUSE USING INERTIAL SENSOR FOR HUMAN-COMPUTER INTERACTION

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Abstract

Pointing devices commonly used today, including the modern computer mouse, can only be operated manually. For people with physical impairments, usage can be problematic due to a limited ability to operate such devices. Therefore, this study was inspired to conduct research on designing and evaluating an appropriate mouse-substitution system for individuals who are physically impaired. The design of the system uses an inertial measurement unit (IMU) that is a fusion of a gyroscope and an accelerometer sensor in which the sensor is attached to a user's upper arm to recognise physical gestures. Any gestures performed by the upper arm are then mapped and used to manipulate mouse cursor movements on computer devices. The design of the "clicking" method uses both an electromyograph (EMG) sensor and a bend sensor. This study evaluates two input devices; one is a combination of an IMU and an EMG sensor, and the other is an input device that is a combination of an IMU and a bend sensor. Fitts' Law formula and the ISO/TS 9241-411: Ergonomics of human-system interaction standard were used to evaluate quantitative performance and level of comfort. The quantitative results show that the average throughput (*TP*) of the first input device (2.30 *bps*) differs greatly, statistically, in comparison to the second input device (1.75 *bps*). Similarly, the average movement time (t_m) revealed that there is a statistically significant difference between the first input device (1.98 *s*) and the second input device (2.67 *s*). The qualitative results show that the comfort levels of the first input device are superior to those of the second input device. It concludes that the combination of IMU and EMG as a pointing and clicking apparatus revealed better performance than the combination of IMU and bend sensor.

Keywords: upper-arm mouse, ISO/TS 9241-411, IMU, electromyograph, bend sensor

1. Introduction

1.1. Background

Pointing-device development has, in recent times, reached new milestones in comfort and convenience of use. Moreover, interacting with computers, such as playing games using controllers or carrying out daily tasks, has become much easier.

Most pointing devices require human motoric functions to operate, e.g., moving a mouse with the hand. Despite their convenience for the average user, such devices prove difficult – and sometimes impossible – for people with physical impairments to effectively operate. In 2012, 74.75% of people with special needs or disabilities in Indonesia were unemployed, and 60.33% failed to continue their education, with many stopping at the sixth grade (elementary school). These data were collected in a study of 1,389,420 people with special needs [1]. usi. Perhaps a new mouse for the people with special needs could create new job opportunities using a computer for them, and this is the motivation of the present study.

These facts reinforce the background of our research orientation's minimum goal of helping people with disabilities or physical impairments find an efficient and effective method to interact with and manipulate computer interface systems.

1.2. Related work

As can be seen in [2], inertial measurement unit (IMU) technology can be used for pointing devices and is currently in widespread use in controller devices (mostly game controllers) [3, 4]. IMUs consist of three axes and angles called Euler angles, similar to how the human body is aligned with three axes consisting of the sagittal, frontal (coronal), and transverse axes.

The use of arm movement to emulate the mouse cursor is studied in [5]. In this study, the use of a jerking of the upper arm as a clicking method resulted in poor performance, i.e., low throughput and slow movement time. The other study using expensive industrial IMU and EMG (electromyograph) as a mouse emulator with arm movement for the hand amputees people is in [6], and the placement of the EMG and IMU were in the wrist and forearm. The placement of sensors in the wrist and forearm limits users who do not have a forearm. Therefore, in this study, the placement of sensors was proposed in the upper arm. Figure 1a illustrates the related work in [5] by using a smartphone attached to the upper arm, while Fig. 1b illustrates the work of [6] by using industrial IMU+EMG attached to the forearm.

By using technical specifications according to ISO/TS 9241-411, this study expects to fulfil ergonomic aspect requirements. Our research focus is on individuals with lower-arm difficulties related to amputations, prenatal disabilities, accidents, and genetic disorders. In all cases, the shoulders remain functional. The expectation is that this group will be able to use the proposed devices. The novelty of the proposed device is on the placement of sensors (i.e., on the upper arm), the use of low-cost IMU, and a standard evaluation procedure using ISO/TS 9241-411. In this study, the gesture of the right upper arm movement would emulate the mouse cursor, and the clicking action comes from EMG or bend sensor. The study proposed two kinds of devices, i.e., device #1 is the combination of IMU and EMG,

and device #2 is the combination of IMU and bend sensor. The two input devices will be compared quantitatively and qualitatively using the measurement standard of ISO/TS 9241-411. Using the proposed system, the researchers would like to contribute by reducing the number of people with special needs who are unemployed and increase human welfare through new job opportunities using an upper-arm mouse that will be created.

(a) (b)

Fig. 1. a) Related work using sensor in smartphone and jerk of upper arm (top view); b) Related work using industrial IMU and EMG sensor attached on the forearm

2. Materials and Method

Pointing devices or input devices allow users to move digital cursors on a computer interface. Our research is aimed at the construction of an input-device system that can move digital cursors and conduct clicking operations. The use of shoulder movements provides digital inputs to these cursors. Because the human shoulder can articulate in a three-dimensional plane, an IMU that can map and measure shoulder movements in Euler angles is used. To conduct clicking operations, an EMG or bend sensors is used: an EMG to detect muscle contractions that occur in the upper arm and bend sensors to detect shoulder abduction and adduction movements to provide the input for clicking operations. This study compares the performance of the EMG and the bend sensor, which are the candidate devices to perform the clicking operations. In order to operate input devices easily without the inconvenience of cables and wires, the proposed system employed Bluetooth technology as the best option to provide low-range wireless transmissions. The input device block diagram can be seen in Fig. 2. The combination of the EMG and IMU will be called the first input device or device #1; the combination of the bend sensor and IMU will be called the second input device or device #2. This research also measured a standard mouse as the base input device; it is compared to device #1 and device #2 using statistical analysis. This provides the best recommendations to determine which of the two alternative input devices is most suitable for users with lower-arm disabilities and to obtain results for developing further research in human-computer interaction using an IMU-based sensor.

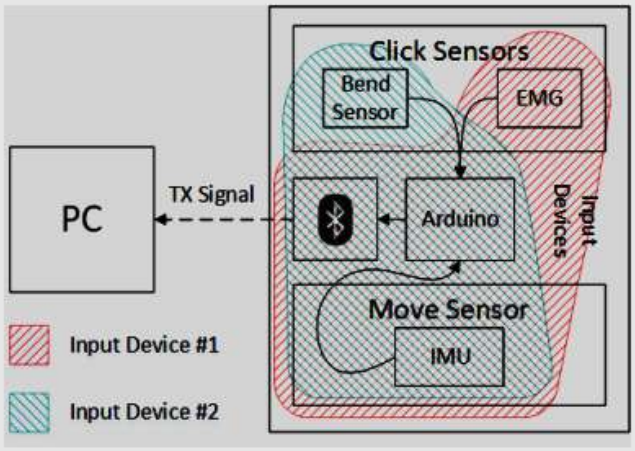


Fig. 2. Block diagram of input devices

The IMU is a combination of sensors that calculate linear velocity range, commonly called an accelerometer, and angular velocity, commonly called a gyroscope [7]. The IMU has several advantages, including low cost, lower power consumption, and no requirements for extension components [8]. The term physical impairment is used to describe any condition that limits a person's capability to perform physical activities [9]. Electromyography is a medical electrodiagnostic method for evaluating and recording electrical activities produced by skeletal muscles [10]. Bluetooth is a wireless technology for data transfer with low-range transmissions using UHF radio waves [11].

The design for the input devices is as follows. The first step is the installation of an IMU combined with an EMG, as shown in [6] (with differing device placement and installation methods). An EMG is mounted on the left upper arm, precisely on the biceps muscle, and the IMU on the right upper arm. The second input device consists of the combination of the IMU and bend sensor, which is mounted on the left shoulder. The IMU operates the cursor movement, while the EMG muscle sensor and bend sensor perform the clicking operations. The purpose of placing the IMU and the EMG or bend sensor on different arms is to divide the tasks and create clear and separate data for clicking operations and cursor movements. The configuration of the proposed device is illustrated in Fig. 3, and each part is discussed as follows:

1. IMU GY-951
   IMU with nine degrees of freedom (9 DoF), with calculations for fusion sensors on IMU devices using DCM (Direct Cosine Matrix) as in [12].
2. Arduino Uno
   The Arduino Uno, an open-source microcontroller board developed by the Arduino company, has the function of connecting all the components in the proposed device and managing data for transmissions over Bluetooth signals.
3. HC-05
   The HC-05 is a hardware device based on the UART (universal asynchronous receiver-transmitter) interface that can be set to send and receive Bluetooth signals.

4. Bend sensor or flex sensor
   Bend sensor (flex) is a sensor that measures the amount of motion generated by bending or deflection. The sensor is used for device #2 in this study.
5. MyoWare
   EMG MyoWare is used to detect muscle contractions through electrode pads attached to the subject's biceps muscle or other areas indicated as human skeletal muscle. The sensor is used for device #1 in this study.
6. Xsens MTw Awinda motion tracker
   An industrial standard wireless IMMU (inertial-magnetic measurement unit). This device is used as a gold standard/reference for measuring the angle error of the GY-951, an IMU.
7. Awinda station/master
   Provides an interface between host (PC) running the software from Xsens and one or more MTw Awinda units [13].

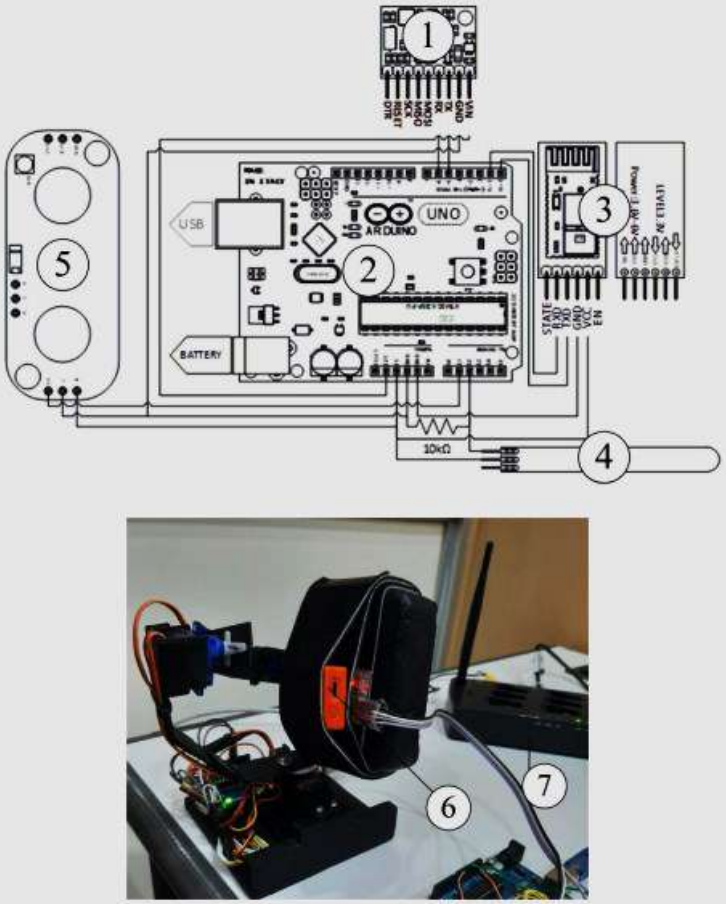


Fig. 3. Assembly of the input devices; each number aligns with the numbering of the device details noted in the text

Inaccuracies in data transmitted by the GY-951 IMU are caused by arm jitter and noises that need to be filtered out. A filter that works in real-time is the moving average, which is useful for filtering all data on yaw, pitch, and rolls issued by GY-951 devices.

The design for the software is described in Fig. 4. The first step is the gesture acquisition of right upper arm and click action from the sensor in the left upper arm. On the left side of the branch in the flowchart, the moving-average filter intends to reduce the signal noises from IMU and arm movement jitter. On the right side of

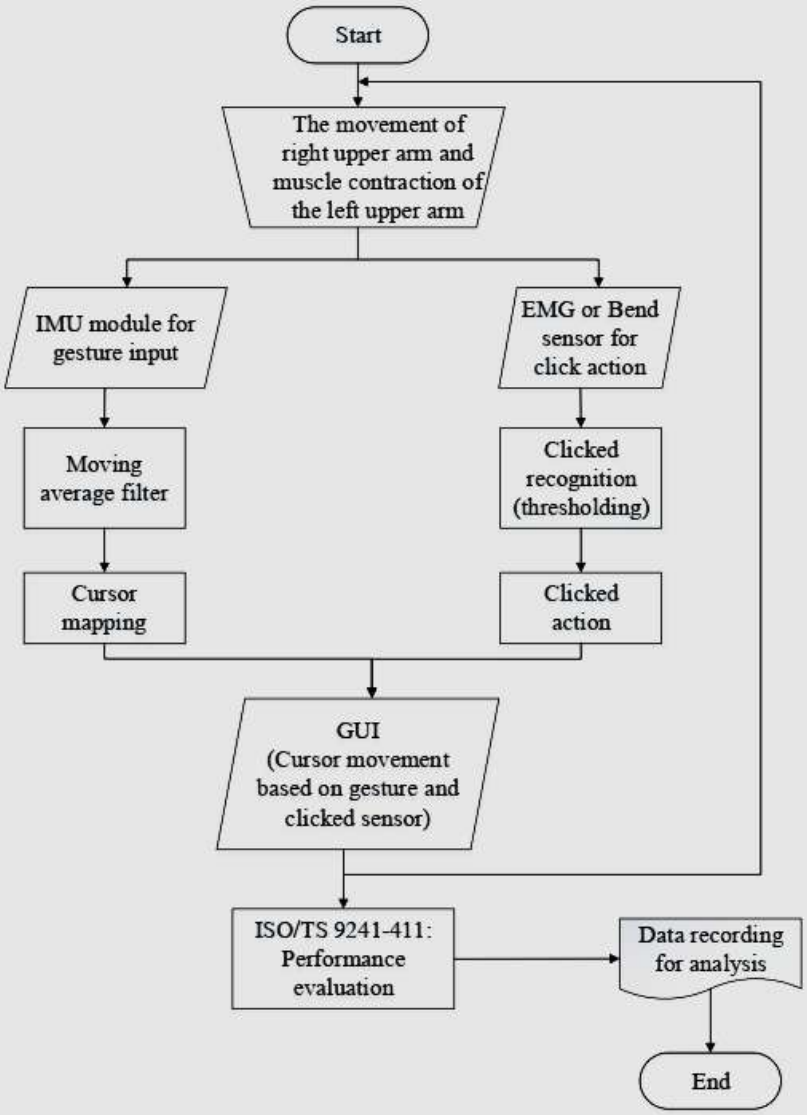


Fig. 4. The flowchart of software

the branch is the clicked recognition using the threshold method. The result of cursor mapping, which will be discussed in part 2.3, combined with the clicked action, would be combined. The combination between cursor mapping and clicked action results in PC monitor use as daily with a mouse. However, for experiment purposes, the option to collect the cursor coordinates in a .csv file is available in the GUI.

2.1. Evaluation design based on ISO/TS 9241-411 and Fitts' Law

Fitts' Law is used to measure performance efficiency using the parameter known as throughput (*TP*). Fitts' Law is a theorem that describes the relations between the time of movement (t_m), distance, and accuracy required by humans to perform tasks in a short time [14], where I_D (Index of difficulty) is a derivative of the Fitts' Law equation. The ISO/TS 9241-411 comprises three types of measurement: one-directional tapping, multidirectional tapping, and dragging and tracing [15]. There are four levels of difficulty (*modes*) that depend on d and W. The equations (1) to (4) are adapted from ISO/TS 9241-411 [15] The formula for determining the index of difficulty is Eq. (1), where:

I_D = Fitts' Index of difficulty or Shannon formula measured in bits per second (bps)
d = distance (between targets) in pixel(s)
W = width (target width) in pixel(s)

$$I_D = log_2\left(\frac{d+W}{W}\right) \quad (1)$$

There are four categories of difficulty: **(i)** *mode* 1, high difficulty: $I_D > 6$; **(ii)** *mode* 2, medium difficulty: $4 < I_D \leq 6$; **(iii)** *mode* 3, low difficulty: $3 < I_D \leq 4$; and **(iv)** *mode* 4, very low difficulty: $I_D \leq 3$.

Eq. (2) is the calculation of throughput (*Tp*) with units of bits per second (bps).

$$T_P = \frac{Effective\ index\ of\ difficulty}{Movement\ time} = \frac{I_{De}}{t_m} \quad (2)$$

where the I_{DE} and W_e are as follows:

$$I_{De} = log_2\left(\frac{d+W_e}{W_e}\right) \quad (3)$$

$$W_e = 4.133\ S_x \quad (4)$$

with annotations as shown below:
I_{De} = effective Fitts' Index of Difficulty in bps
t_m = time of movement in second(s)
W_e = target width (effective) of the displayed target in pixel(s)
S_x = standard deviation of collected x coordinates of each tapping in pixel(s)

For the aim of this study, the modification of ISO/TS 9241-411's one-directional tapping test is employed. The test consists of two horizontal and vertical orientations, as illustrated in Fig. 5. Its purpose is to measure the performance of horizontal and vertical movements. Table 1 presents the difficulty level based on Eq. (1).

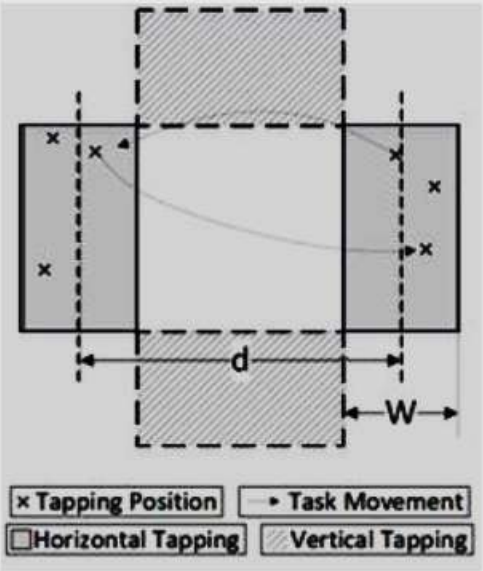


Fig. 5. The two-directional tapping test (horizontal and vertical tapping test), which includes variables W = width and d = distance

Table 1. The design of d and W in four difficulty levels

Mode	Distance (pixels)	Width (pixels)	ID (Index of Difficulties) (bits)	Level
1	650	10	**6.04**	**High**
2	600	20	**4.95**	**Medium**
3	500	60	**3.22**	**Low**
4	350	50	**3.00**	**Very Low**

In addition, ISO/TS 9241-411 provides a qualitative data-collection instrument in the form of assessment questionnaires, i.e., assessments of comfort and effort. The questions assess the use of a standard mouse and the two proposed input devices. Assessments of various types of comfort are evaluated by 12 questions in the form of a seven-point Likert-type scale. The 12 questions consist of seven questions regarding comfort assessment and five questions regarding fatigue assessment. The effort assessment uses the Borg RPE 0-10 scale (rating of perceived exertion), which measures the level of effort required by the arms, shoulders, and neck. The Borg scale ranges from 0 to 10; the higher the score, the greater the effort required.

To further our knowledge, the Edinburgh Handedness Inventory [16] was used to understand each subject's hand preference; three categories are assessed: right-handed, left-handed, and ambidextrous.

2.2. Moving-average filter

The usable angles from the sensor in this study are roll and pitch; yaw is not used, as it is caused by the influence of Earth's magnetic field. The recursive expression of moving-average filter is utilised to reduce the effects of arm jitter and noise. Eqs. (5) and (6) adapted from [17] were implemented in the software.

$$\bar{X}_{R_k} = \bar{X}_{R_{k-1}} + \frac{X_{R_k} - X_{R_{k-n}}}{n} \quad (5)$$

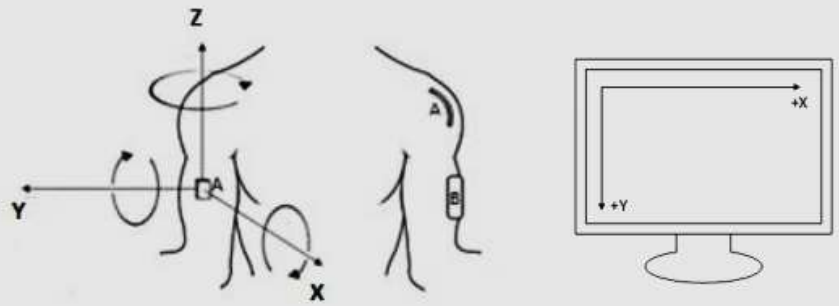
$$\bar{X}_{P_k} = \bar{X}_{P_{k-1}} + \frac{X_{P_k} - X_{P_{k-n}}}{n} \quad (6)$$

Where,

X_{Rk}, X_{Pk} = Roll or pitch data at k
$\bar{X}_{Rk-1}$, $\bar{X}_{Pk-1}$ = Moving average of roll or pitch before k
$\bar{X}_{Rk}$, $\bar{X}_{Pk}$ = Moving average of roll or pitch at k
n = Number of sampled data

2.3. Sensor orientation to cursor-movement translation

Cursor-movement translation is the process of translating sensor orientation (three-dimensional) into inputs for cursor control (two-dimensional), as illustrated in Fig. 5. The roll angle is the rotation in the y-axis (θ_y), while the pitch angle is the rotation in the x-axis (θ_x), as shown in Fig. 6(a). The rotation in the roll angle was mapped into the x-axis of the monitor screen, and the inverse of the pitch angle was mapped into the y-axis of the monitor screen, as shown in Fig. 6(b), also used by other studies [18, 19].



(a) **(b)**

Fig. 6. Orientation to cursor translation: (a) Orientation of sensor; A is a bend sensor and B is EMG set; (b) Cursor-space axes

Eqs. (7) and (8) are the formulas used in C# software to translate the orientation to the cursor position (A_x, A_y) on the monitor screen.

$$A_x = \frac{\theta_y - \min(\theta_y)}{\max(\theta_y) - \min(\theta_y)} . (\max(A_x) - min(A_x)) \quad (7)$$

$$A_y = \frac{\max(\theta_x) - \theta_x}{\max(\theta_x) - \min(\theta_x)} . (\max(A_y) - min(A_y)) \quad (8)$$

2.4. Click-detection method

As shown in Fig. 6(a), the placement of click-detection sensors is on the left upper arm. The bend sensor (flex) is marked by A and EMG sensors by B.

The first proposed device, device #1, used the EMG signal. The electrode of surface EMG was placed on the biceps brachii muscle. The single threshold was determined by the adaptation formula from [20], as shown here in Eq. (9):

$$T_h = \gamma . \max(x_i) \quad (9)$$

where x_i is the EMG signal without muscle activity, and γ is the constant determined by the experimentation.

Device #2, the second proposed device, used the bend sensor for clicking operations; this works by straightening or aligning the shoulders. The decision on the clicking action is determined by the single threshold, the value of which was determined by the experiment. The relation between voltage and deflection is shown in Fig. 7, as well as an illustration of the single-threshold line.

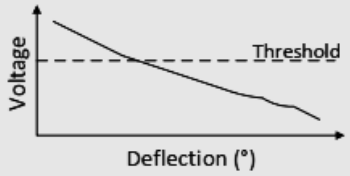


Fig. 7. Voltage and deflection relation graphic: The line of single threshold for the bend (flex) sensor

2.5. Experimental scenario

A total of 12 people participated as subjects in this study. Each one performed testing tasks (trials) as many as 50 times; these included 25 horizontal tappings and 25 vertical tappings, among other tasks. The two-directional tapping test task is shown previously in Fig. 5. The error was calculated when a subject tapped outside the rectangular area of the target.

The subjects were divided into three groups using a Latin square. The Latin square is used to reduce the order effect, i.e., learning effect, practice effect, fatigue effect, and sequence effect as suggested in [21]. The experiment using within-subject design indicates that each subject tests three devices, i.e., a standard mouse, input device #1 (IMU+EMG), and input device #2 (IMU+Bend sensor). The designed tasks have four modes of difficulty level, as shown in Table 1, and each of these was repeated in three blocks. This means that the total record of tap coordinates per subject is 50 trials *x* 4 modes *x* 3 blocks *x* 3 devices.

The reliability of all items in the questionnaire used for qualitative analysis was determined by Cronbach's alpha. The statistical difference in T_P and t_m among the three devices was performed using the Wilcoxon-signed rank test.

3. Experiment Results

The preferred handedness of subjects was determined using the Edinburgh Handedness Inventory; 91.67% were right-handed, and 8.33% were ambidextrous, while our sample had no left-handed users. Figure 8 shows the device worn on the torso and arm, accompanied by the labelled components. The black marks and labels are intended to show the names of the device's components and their placement. The EMG electrodes have three placement points. The first is the midpoint and is a cable leading to an electrode (*pad*) placed on the midsection of the targeted muscle. The second is the endpoint and is a cable leading to an electrode placed adjacent to the middle electrode toward the end of the targeted muscle. The third location is the reference point and is a cable leading to the reference electrode, usually placed on a bony area of the body, i.e., elbow.

Fig. 8. Input devices mounted on the torso and lower arm, including labels for all device parts

In the data collected from subjects, the average values of throughput, moving time (t_m), and error rate were calculated for all subjects for three input devices: a standard mouse, device #1 (IMU+EMG), and device #2 (IMU+bend sensor). Table 2 provides the experimental results in detail. The representation of Table 2 as a graph is illustrated in Fig. 9

Table 2. Experimental results (in detail)

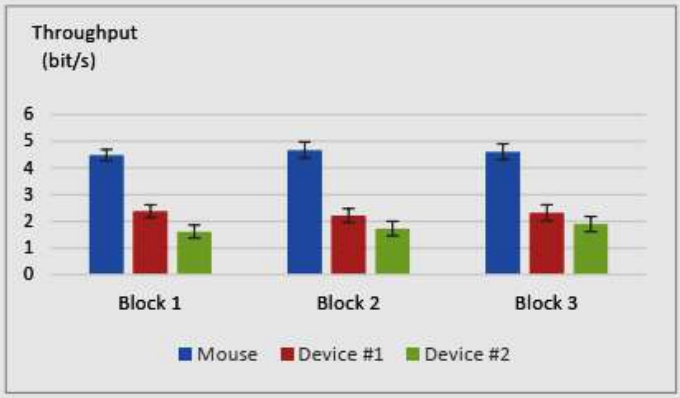
B[1)]	M[2)]	ID (bits)	Mouse				Device #1 (IMU+EMG)				Device #2 (IMU+Bend)			
			w_e (pixel)	ID_e (bits)	t_m (s)	TP (bps)	w_e (pixel)	ID_e (bits)	t_m (s)	TP (bps)	w_e (pixel)	ID_e (bits)	t_m (s)	TP (bps)
1	1	3.00	34.36	3.48	0.82	4.27	38.84	3.32	1.45	2.29	39.59	3.30	1.83	1.80
	2	3.22	42.95	3.66	0.85	4.32	42.85	3.66	1.51	2.43	47.38	3.53	2.21	1.60
	3	4.95	17.24	5.16	1.07	4.80	21.58	4.85	1.77	2.73	21.03	4.88	2.66	1.84
	4	6.04	9.76	6.08	1.33	4.55	12.09	5.77	2.79	2.07	11.97	5.79	4.69	1.23
2	1	3.00	37.24	3.38	0.79	4.26	38.54	3.33	1.43	2.34	41.40	3.24	1.73	1.88
	2	3.22	44.19	3.62	0.80	4.50	45.65	3.58	1.44	2.48	45.10	3.60	1.75	2.06
	3	4.95	16.46	5.23	1.05	5.00	20.81	4.90	2.16	2.26	20.85	4.90	2.97	1.65
	4	6.04	9.52	6.11	1.24	4.93	11.92	5.79	3.26	1.78	12.14	5.77	4.38	1.32
3	1	3.00	37.74	3.36	0.79	4.25	38.94	3.32	1.34	2.47	38.10	3.35	1.67	2.01
	2	3.22	43.58	3.64	0.83	4.38	44.97	3.60	1.36	2.65	43.72	3.64	1.62	2.24
	3	4.95	16.82	5.20	1.06	4.93	20.09	4.95	2.14	2.32	20.71	4.91	2.61	1.88
	4	6.04	9.30	6.15	1.26	4.87	12.48	5.73	3.14	1.83	12.20	5.76	3.93	1.47
Mean					**0.99**	**4.59**			**1.98**	**2.30**			**2.67**	**1.75**

[1)]B = block

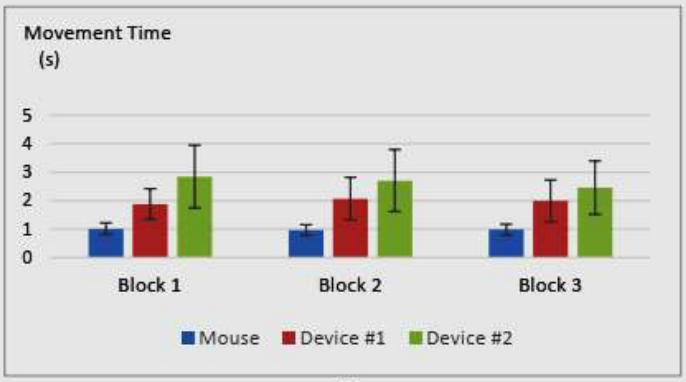
[2)]M = mode (difficulty level)

The detailed results of Table 2 and Fig. 9 are as follows:

a. Mean throughput for mouse (4.59 bps), device #1 (2.3 bps), and device #2 (1.75 bps);
b. Mean time of movement for mouse (0.99 s), for device #1 (1.98 s), and for device #2 (2.67 s).



(a)



(b)

Fig. 9. Throughput and movement time as a function of experiment block for mouse and the proposed device: device #1 and device #2

The mean error rate for the mouse is (2.81%); for device #1, it is (21.64%), and for device #2 (20.49%). The details of the error rates are represented in Table 3, with the error rate data for each evaluation block and the error rate data per mode, respectively.

Table 3. Error rate for each device

Device	Error rate per experiment block (%)			Error rate per difficulty level (%)				Average error rate (%)
	1	2	3	Mode 1 (very low)	Mode 2 (low)	Mode 3 (medium)	Mode 4 (high)	
Mouse	2.79	2.42	3.21	1.28	0.56	3.06	6.33	**2.81**
Device #1	22.17	21.54	21.21	2.83	3.50	22.39	57.83	**21.64**
Device #2	20.63	19.92	20.92	4.78	3.39	20.06	53.72	**20.49**

Figure 10 shows the error rate in four difficulty levels. It shows that the graph increases sharply for device #1 and device #2 on mode 3 and mode 4.

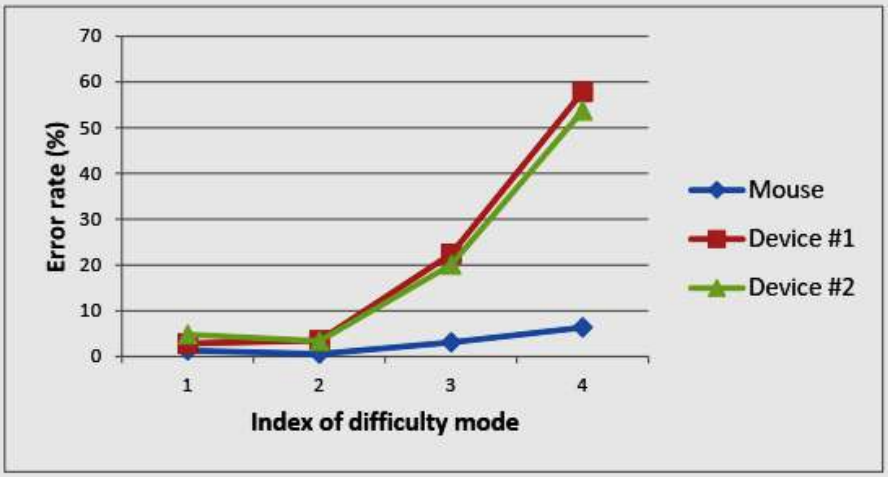


Fig. 10. Error rate per index of difficulty level

3.1. Throughput (*TP*) and time of movement (t_m): Quantitative analysis

The Shapiro–Wilk test was conducted to test normality. It indicated that *TP* for the mouse is $p = .049$, which indicates non-normality; however, device #1 and the device #2 had normal distributions, $p = .478$ and $p = .924$, respectively. The Friedman test showed a statistical difference in *TP* scores between the mouse, device #1, and device #2 ($\chi^2 = 24$, $p = .000$). The data are available in a shared document. The link is available at https://bit.ly/2EGAvBM.

Next, pairwise comparison among the devices was assessed using the Wilcoxon signed-rank test; the throughput results are shown below:

1. The throughput for the mouse is significantly higher than for the device #1 value ($Z = -3.059, p = 0.002$).

2. The throughput for the mouse is significantly higher than for the device #2 value ($Z = -3.059, p = 0.002$).
3. The throughput for the device #1 is significantly higher than for the device #2 value ($Z = -3.064, p = 0.002$).

The results of the Shapiro–Wilk test showed that t_m was not normally distributed for the mouse *($p = .035$)*, the input device #1 *($p = .016$)*, and the input device #2 *($p = .037$)*. The t_m scores for the three devices showed statistical differences using the Friedman test *($\chi^2 = 24, p = .000$)*. The results of the pairwise comparison using the Wilcoxon signed-rank test indicate that the t_m for the mouse is significantly faster than for the two input devices *($Z = -3.061$, $p = 0.002$ and $Z = -3.059$, $p = 0.002$)*. Also, the t_m for the first and second input devices show a significant difference *($Z = -3.059, p = 0.002$)*. Device #1 was faster than device #2, as shown in Table 2.

3.2. Assessments of comfort and effort: Qualitative analysis

The means of the assessments of comfort and fatigue are described in Table 4. Cronbach's alpha indicates that the reliability level of the 12-item questionnaire is 0.816. The pairwise comparison using the Wilcoxon signed-rank test shows that the comfort level for the mouse is significantly higher than for the first input device ($Z = -7.15, p = .00$), as well as significantly higher than for the second input device ($Z = -7.67, p = .00$). The assessment of comfort for device #1 is significantly higher than for device #2 ($Z = -4.56, p = .00$).

Table 4. The mean results of comfort and fatigue for each device

*Assessment**	Interaction		
	Mouse	Device #1	Device #2
Mean of Comfort	6.44	4.73	3.97
Mean of Fatigue	6.48	6.52	6.23

*Using a 7-point Likert-type scale, 7 is superior

For the fatigue test, the Wilcoxon signed-rank pairwise comparison of fatigue level in the arm, shoulder, and neck indicates that all pairs were not significantly different. In regard to details, the assessment of fatigue for using the mouse is not significantly lower than for device #1 and device #2. The assessment of fatigue for device #1 is not significantly lower than for device #2.

Figure 11 shows responses in detail of each questionnaire; the horizontal axis shows the scale of impression in a seven-point Likert-type scale.

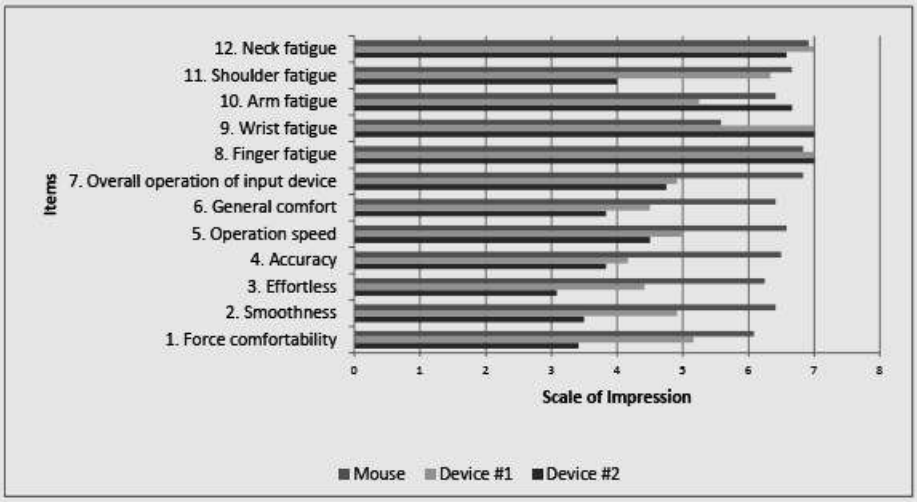


Fig. 11. Results of comfort and fatigue questionnaire

3.3. Special report on the device usage in an individual with a special need

One of our subjects has a special need related to a limb disability. The data collected are from device #2 using the IMU and bend sensor; therefore, this result represents a special report, and the data was not included in our statistical calculations. The reported *TP* using device #2 is 1.05 bps; while the t_m is 4.4 seconds. The mean of the error rates is 28.17%. Figure 12 shows an input device mounted on the body of a subject with a special need.

Fig. 12. Input device mounted on the torso and lower arm of a physically impaired subject

Through qualitative data processing, the average score for the questionnaire on the independent assessment of comfort is 5.67 based on a seven-point Likert-type scale, while effort has a value of 2.0 based on the 10-item Borg RPE scale.

Anecdotal data collected from interviews with subjects show that device #2 was comfortable to use and only required the user to learn how the device functions and how to make necessary adjustments. It is expected that further developments can make this device smaller and more convenient to use.

4. Discussion

A study of mouse cursor placement and click action using IMU and EMG was also proposed in [6], using five EMGs with the placement of these on the subject's forearm. However, in this study, only one EMG at the upper arm was used. The IMU applied in [6] used the Xsens MTx IMU, which is the standard IMU for reference; this means that the study in [6] does not have an IMU design step. However, in the present study, the aim was to develop a prototype using GY-951 IMU; the cost would be greatly reduced using GY-951 in contrast to Xsens MTx. Our study also follows the standard of measurement for the new pointing device using ISO/TS 9241-411.

In the present study, the throughput mean of the mouse is 4.59 bps, in line with the results of other researchers, for example, in [22] and [23], where the range for mouse throughput is 3.7–4.9 bps. The error rate, as shown in Table 3, indicates that the design of a Latin square worked well, as the error rate between the experiment blocks did not show large changes; however, the mode 1 to mode 4 error rate showed an increasing tendency as the difficulty level increased.

The mouse provides better results in regard to comfort, fatigue, and error rates compared to the two proposed input devices, #1 and #2. However, this is not the intended purpose of our study since the mouse is used only as a baseline research apparatus. Our main purpose was a comparison between the first and second proposed input devices using the IMU+EMG and IMU+bend sensor, respectively. This study finds that the performance of the IMU+EMG to be significantly better than that of the IMU+bend sensor based on throughput, movement time, and assessment of comfort, according to our statistical calculations in the experimental results section.

5. Conclusions

Several concluding remarks are offered from this study. The input devices developed as part of our study are viable alternatives to mouse devices for people with physical impairments or those who are unable to use their hand to operate a standard mouse following an injury. Further development is still needed to increase throughput and to minimise time of movement and error rates. The first proposed input device (IMU+EMG) is assessed to be better than the second one (IMU+bend) based on larger throughput, faster movement time, and greater comfort.

The details of the quantitative and qualitative result are as follows: The quantitative result shows that the throughput of device #1 is significantly higher than device #2 ($Z = -3.064$, $p = 0.002$). While the movement time also shows device #1 is faster than device #2, the differences of both devices are statistically significantly different ($Z = -3.059$, $p = 0.002$). The qualitative result was concluded from comfort and fatigue questionnaires. The result shows that the assessment of comfort for device #1 is significantly higher than device #2 ($Z = -4.56$, $p = .00$). However, the fatigue of device #1 and device #2 does not differ statistically,

although device #1 shows slightly higher value.

For future study, the use of higher EMG quality to improve results, as well as filtering methods in IMU using sensor fusion rather than DCM with the potential for better precision, should be explored.

Nomenclatures

A_x	Cursor position x at display
A_y	Cursor position y at display
d	Distance (between the target), pixel
I_D	Fitts' Index of Difficulty or Shannon formula, bit
I_{De}	Effective Fitts' Index of Difficulty, bit
n	Number of sampled data
S_x	Standard deviation of collected x coordinates of each tapping, pixel
T_h	Threshold
T_p	Throughput, bps
t_m	Time of movement, second
W_e	Effective Width (target width), pixel
W	Width (target width), pixel
x_i	EMG signal
X_{Rk}	Roll data at k, deg
X_{Pk}	Pitch data at k, deg
$\bar{X}_{Rk-1}$	Moving average of roll before k
$\bar{X}_{Pk-1}$	Moving average of pitch before k
$\bar{X}_{Rk}$	Moving average of roll at k
$\bar{X}_{Pk}$	Moving average of pitch at k

Greek Symbols

γ	Constant
θ_y	Roll angle, deg
θ_x	Pitch angle, deg
$\chi 2$	Chi-square, statistical method

Abbreviations

EMG	Electromyograph
GUI	Graphical User Interface
ISO	International Organization for Standardization
IMU	Inertial Measurement Unit
IMMU	Inertial-Magnetic Measurement Unit

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