UNIVERSITAS
MA CHUNG

SURAT PERJANJIAN PENUGASAN
PENELITIAN TAHUN JAMAK
SKIM PENELITIAN TERAPAN UNGGULAN PERGURUAN TINGGI
TAHUN ANGGARAN 2019
Nomor: 008/MACHUNG/LPPM/SP2H-LIT-MULTI/III/2019

Pada hari ini **Rabu** tanggal **Duapuluhtujuh** bulan **Maret** tahun **Dua Ribu Sembilanbelas**, kami yang bertandatangan dibawah ini :

1.Dr. CHATIEF KUNJAYA, M.Sc.	:	Rektor Universitas Ma Chung, dalam hal ini bertindak untuk dan atas nama Universitas Ma Chung, yang berkedudukan di Villa Puncak Tidar N-01 Malang, untuk selanjutnya disebut **PIHAK PERTAMA;**
2.Dr.Eng ROMY BUDHI, S.T, M.T	:	Dosen Program Studi Teknik Informatika Universitas Ma Chung, dalam hal ini bertindak sebagai Ketua Pelaksana Penelitian Tahun Jamak skim Penelitian Terapan Unggulan Perguruan Tinggi, untuk selanjutnya disebut **PIHAK KEDUA**.

Surat Perjanjian Penugasan ini berdasarkan pada Surat Perjanjian Penugasan Penelitian Tahun Jamak Tahun Anggaran 2019, Nomor: 041/SP2H/LT/MULTI/L7/2019, tanggal 26 Maret 2019.

PIHAK PERTAMA dan **PIHAK KEDUA**, secara bersama-sama sepakat mengikatkan diri dalam suatu Surat Perjanjian Penugasan Penelitian Tahun Jamak skim Penelitian Terapan Unggulan Perguruan Tinggi dengan ketentuan dan syarat-syarat sebagai berikut:

Pasal 1
Lingkup Penugasan

(1) **PIHAK PERTAMA** memberi tugas kepada **PIHAK KEDUA**, dan **PIHAK KEDUA** menerima tugas tersebut untuk melaksanakan dan menyelesaikan Penelitian Tahun Jamak skim Penelitian Terapan Unggulan Perguruan Tinggi dengan judul **"Teknologi Tepat Guna untuk Penyandang Disabilitas Lengan dalam Mengoperasikan Komputer"**.
(2) Pelaksana Penelitian Tahun Jamak skim Penelitian Terapan Unggulan Perguruan Tinggi sebagaimana judul pada ayat (1) adalah sebagai berikut:

Ketua	:	Dr.Eng ROMY BUDHI, S.T, M.T
Anggota 1	:	MOCHAMAD SUBIANTO, M.Cs
Anggota 2	:	PAULUS LUCKY TIRMA IRAWAN, S.Kom, M.T
Anggota 3	:	-

(3) **PIHAK KEDUA** bertanggungjawab penuh atas pelaksanaan tugas dimaksud pada ayat (1).

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Pasal 2
Dana Penelitian

(1) Dana untuk melaksanakan Penelitian Tahun Jamak skim Penelitian Terapan Unggulan Perguruan Tinggi untuk Tahun Anggaran 2019 dengan judul sebagaimana dimaksud pada Pasal 1 adalah sebesar **Rp131.220.000 (Seratus Tiga Puluh Satu Juta Dua Ratus Dua Puluh Ribu Rupiah)** sudah termasuk pajak.
(2) Dana tambahan untuk Penelitian dengan judul sebagaimana dimaksud pada Pasal 1 adalah sebesar - **(Nol Rupiah)**.
(3) Dana Penelitian sebagaimana dimaksud pada ayat (1) dan (2) dibebankan pada Daftar Isian Pelaksanaan Anggaran (DIPA) Direktorat Jenderal Penguatan Riset dan Pengembangan, Kementerian Riset, Teknologi dan Pendidikan Tinggi.

PASAL 3
Jangka Waktu

(1) Surat Penugasan Penelitian ini dilaksanakan dalam jangka waktu 2 Tahun, yang mulai berlaku sejak tahun 2019.
(2) Keberlanjutan penelitian sebagaimana tercantum dalam Pasal 1 ayat (1) ditentukan berdasarkan hasil penilaian atas capaian tahun berjalan yang dilakukan oleh Komite Penilaian Keluaran Penelitian dan/atau Reviewer Keluaran Penelitian.

Pasal 4
Tata Cara Pembayaran Dana Penelitian

(1) **PIHAK PERTAMA** akan membayarkan Dana Penelitian kepada **PIHAK KEDUA** Rp266.720.000 dalam jangka waktu 2 Tahun.
(2) Pendanaan penelitian sebagaimana dimaksud pada ayat (1) dibayarkan **PIHAK PERTAMA** kepada **PIHAK KEDUA** secara bertahap:
   a. Rp131.220.000 *(Seratus Tiga Puluh Satu Juta Dua Ratus Dua Puluh Ribu Rupiah)* untuk Tahun Pertama.
   b. Rp135.500.000 *(Seratus Tiga Puluh Lima Juta Lima Ratus Ribu Rupiah)* untuk Tahun Kedua.
   c. - *(-)* untuk -
(3) Pendanaan penelitian sebagaimana dimaksud pada ayat (2) huruf a, diberikan dengan ketentuan apabila revisi proposal penelitian telah diunggah ke laman SIMLITABMAS.
(4) Pendanaan penelitian sebagaimana dimaksud pada ayat (2) huruf b dan/atau huruf c, diberikan berdasarkan hasil penilaian atas capaian tahun sebelumnya yang dilakukan oleh Komite Penilaian Keluaran Penelitian dan/atau Reviewer Keluaran Penelitian.
(5) Biaya Luaran Tambahan sebesar - *(Nol Rupiah)* Tahun Anggaran 2019 dibayarkan kepada **PIHAK KEDUA** setelah dilakukan penilaian Luaran Tambahan sebagaimana dimaksud pada ayat (2).
(6) Dana Penelitian sebagaimana dimaksud pada ayat (1) akan disalurkan oleh **PIHAK PERTAMA** kepada **PIHAK KEDUA** ke rekening sebagai berikut:

Nama	:	Dr.Eng ROMY BUDHI, S.T, M.T
Nomor Rekening	:	
Nama Bank	:	BNI

(7) **PIHAK PERTAMA** tidak bertanggung jawab atas keterlambatan dan/atau tidak terbayarnya sejumlah dana sebagaimana dimaksud pada ayat (1) yang disebabkan karena kesalahan **PIHAK KEDUA**.

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Pasal 5
Target Luaran

(1) **PIHAK KEDUA** berkewajiban untuk mencapai target Luaran Wajib Penelitian sebagaimana disebutkan dalam proposal.
(2) **PIHAK KEDUA** diharapkan dapat mencapai target Luaran Tambahan Penelitian sebagaimana disebutkan dalam proposal.
(3) **PIHAK KEDUA** berkewajiban untuk melaporkan perkembangan pencapaian target Luaran sebagaimana dimaksud pada ayat (1) kepada **PIHAK PERTAMA**.

Pasal 6
Hak dan Kewajiban Para Pihak

(1) Hak dan Kewajiban **PIHAK PERTAMA**:
   a. **PIHAK PERTAMA** berhak untuk mendapatkan dari **PIHAK KEDUA** Luaran Penelitian sebagaimana dimaksud dalam Pasal 5;
   b. **PIHAK PERTAMA** berkewajiban untuk memberikan dana Penelitian kepada **PIHAK KEDUA** dengan jumlah sebagaimana dimaksud dalam Pasal 2 ayat (1) dan dengan tata cara pembayaran sebagaimana dimaksud dalam Pasal 4.
(2) Hak dan Kewajiban **PIHAK KEDUA**:
   a. **PIHAK KEDUA** berhak menerima dana Penelitian dari **PIHAK PERTAMA** dengan jumlah sebagaimana dimaksud dalam Pasal 2 ayat (1);
   b. **PIHAK KEDUA** berkewajiban menyerahkan kepada **PIHAK PERTAMA** Luaran Penelitian dan Catatan Harian Pelaksanaan Penelitian;
   c. **PIHAK KEDUA** berkewajiban untuk bertanggungjawab dalam penggunaan dana Penelitian yang diterimanya sesuai dengan proposal kegiatan yang telah disetujui;
   d. **PIHAK KEDUA** berkewajiban untuk menyampaikan kepada **PIHAK PERTAMA** Laporan Penggunaan Dana sebagaimana dimaksud dalam ayat (2) huruf c.

Pasal 7
Laporan Pelaksanaan Penelitian

(1) **PIHAK KEDUA** berkewajiban untuk menyampaikan kepada **PIHAK PERTAMA** berupa Laporan Kemajuan, Surat Pernyataan Tanggungjawab Belanja (SPTB), Laporan Akhir, Luaran Penelitian yang tersusun secara sistematis sesuai pedoman yang ditentukan oleh **PIHAK PERTAMA**.
(2) **PIHAK KEDUA** berkewajiban mengunggah ke laman SIMLITABMAS sesuai batas waktu yang ditentukan Direktorat Riset dan Pengabdian Masyarakat, Direktorat Jenderal Penguatan Riset dan Pengembangan, Kementerian Riset, Teknologi, dan Pendidikan Tinggi, dokumen sebagai berikut:
   a. Catatan harian pelaksanaan Penelitian
   b. Laporan Kemajuan
   c. Surat Pernyataan Tanggungjawab Belanja (SPTB) atas dana penelitian yang telah ditetapkan.
(3) **PIHAK KEDUA** berkewajiban menyerahkan *Hardcopy* Laporan Kemajuan dan Rekapitulasi Penggunaan Anggaran kepada **PIHAK PERTAMA**.
(4) **PIHAK KEDUA** berkewajiban mengunggah ke laman SIMLITABMAS selambat-lambatnya tanggal **16 November 2018** dokumen sebagai berikut:
   a. Catatan Harian Pelaksanaan Penelitian.
   b. Laporan Akhir dan/atau Luaran Wajib dan/atau Tambahan.

(5) Laporan Akhir Penelitian sebagaimana tersebut pada ayat (4) harus memenuhi ketentuan sebagai berikut:
   a. Ditulis dalam format *font Times New Roman* ukuran 12, spasi 1,5, kertas A4;
   b. Di bawah bagian *cover* ditulis:

Dibiayai oleh:
Direktorat Riset dan Pengabdian Masyarakat
Direktorat Jenderal Penguatan Riset dan Pengembangan
Kementerian Riset, Teknologi, dan Pendidikan Tinggi
Sesuai dengan Kontrak Penelitian Tahun Anggaran 2019

Pasal 8
Monitoring dan Evaluasi

(1) **PIHAK PERTAMA** dalam rangka pengawasan akan melakukan Monitoring dan Evaluasi internal terhadap kemajuan pelaksanaan Penelitian Tahun Anggaran 2019 ini sebelum pelaksanaan Monitoring dan Evaluasi eksternal oleh Direktorat Riset dan Pengabdian Masyarakat, Direktorat Jenderal Penguatan Riset dan Pengembangan, Kementerian Riset, Teknologi, dan Pendidikan Tinggi.
(2) **PIHAK KEDUA** yang tidak hadir dalam kegiatan Monitoring dan Evaluasi dan tanpa pemberitahuan tertulis kepada **PIHAK PERTAMA** dapat dikenakan sanksi sesuai ketentuan Direktorat Riset dan Pengabdian Masyarakat, Direktorat Jenderal Penguatan Riset dan Pengembangan, Kementerian Riset, Teknologi, dan Pendidikan Tinggi.

Pasal 9
Penilaian Luaran

1. Penilaian Luaran Penelitian dilakukan oleh Komite Penilai/*Reviewer* Luaran sesuai dengan ketentuan yang berlaku.
2. Apabila dalam penilaian Luaran terdapat Luaran Tambahan yang tidak tercapai maka dana tambahan yang sudah diterima oleh peneliti harus disetorkan kembali ke Kas Negara.

Pasal 10
Perubahan Susunan Tim Pelaksana dan Substansi Pelaksanaan

Perubahan terhadap susunan tim pelaksana dan substansi pelaksanaan Penelitian ini dapat dibenarkan apabila telah mendapat persetujuan tertulis dari Direktur Riset dan Pengabdian Masyarakat, Direktorat Jenderal Penguatan Riset dan Pengembangan, Kementerian Riset, Teknologi, dan Pendidikan Tinggi.

Pasal 11
Penggantian Ketua Pelaksana

(1) Apabila **PIHAK KEDUA** selaku ketua pelaksana tidak dapat melaksanakan Penelitian ini, maka **PIHAK KEDUA** wajib mengusulkan pengganti ketua pelaksana yang merupakan salah satu anggota tim kepada **PIHAK PERTAMA**.
(2) Apabila **PIHAK KEDUA** tidak dapat melaksanakan tugas dan tidak ada pengganti ketua sebagaimana dimaksud pada ayat(1), maka **PIHAK KEDUA** harus mengembalikan dana Penelitian kepada **PIHAK PERTAMA** yang selanjutnya disetor ke Kas Negara.
(3) Bukti setor sebagaimana dimaksud pada ayat (2) disimpan oleh **PIHAK PERTAMA.**

Pasal 12
Sanksi

(1) Apabila sampai dengan batas waktu yang telah ditetapkan untuk melaksanakan Penelitian ini telah berakhir, namun **PIHAK KEDUA** belum menyelesaikan tugasnya, terlambat mengirim laporan Kemajuan, dan/atau terlambat mengirim Laporan Akhir, maka **PIHAK KEDUA** dikenakan sanksi administratif berupa penghentian pembayaran dan tidak dapat mengajukan proposal Penelitian dalam kurun waktu dua tahun berturut-turut.
(2) Apabila **PIHAK KEDUA** tidak dapat mencapai target Luaran sebagaimana dimaksud dalam Pasal 5, maka kekurangan capaian target Luaran tersebut akan dicatat sebagai hutang **PIHAK KEDUA** kepada **PIHAK PERTAMA** yang apabila tidak dapat dilunasi oleh **PIHAK KEDUA**, akan berdampak pada kesempatan **PIHAK KEDUA** untuk mendapatkan pendanaan Penelitian atau hibah lainnya yang dikelola oleh **PIHAK PERTAMA**.

Pasal 13
Pembatalan Perjanjian

(1) Apabila dikemudian hari terhadap judul Penelitian sebagaimana dimaksud dalam Pasal 1 ditemukan adanya duplikasi dengan Penelitian lain dan/atau ditemukan adanya ketidakjujuran, itikad tidak baik, dan/atau perbuatan yang tidak sesuai dengan kaidah ilmiah dari atau dilakukan oleh **PIHAK KEDUA**, maka perjanjian Penelitian ini dinyatakan batal dan **PIHAK KEDUA** wajib mengembalikan dana Penelitian yang telah diterima kepada **PIHAK PERTAMA** yang selanjutnya akan disetor ke Kas Negara.
(2) Bukti setor sebagaimana dimaksud pada ayat (1) disimpan oleh **PIHAK PERTAMA.**

Pasal 14
Pajak-Pajak

Hal-hal dan/atau segala sesuatu yang berkenaan dengan kewajiban pajak berupa PPN dan/atau PPh menjadi tanggungjawab **PIHAK KEDUA** dan harus dibayarkan oleh **PIHAK KEDUA** ke kantor pelayanan pajak setempat sesuai ketentuan yang berlaku.

Pasal 15
Hasil Penelitian

(1) Hak Kekayaan Intelektual yang dihasilkan dari pelaksanaan Penelitian diatur dan dikelola sesuai dengan peraturan dan perundang-undangan.
(2) Setiap publikasi, makalah dan/atau ekspos dalam bentuk apapun yang berkaitan dengan Penelitian ini wajib mencantumkan pihak pemberi dana.
(3) Hasil Pelaksanaan Penelitian ini yang berupa peralatan dan/atau alat yang dibeli dari pelaksanaan Penelitian ini adalah milik Negara yang dapat dihibahkan dihibahkan kepada institusi/lembagal masyarakat melalui Berita Acara Serah Terima (BAST) setelah dilaporkan perolehannya kepada Direktorat Riset dan Pengabdian Masyarakat.

Pasal 16
Penyelesaian Sengketa

Apabila terjadi perselisihan antara **PIHAK PERTAMA** dan **PIHAK KEDUA** dalam pelaksanaan perjanjian ini akan dilakukan penyelesaian secara musyawarah dan mufakat, dan apabila tidak tercapai penyelesaian secara musyawarah dan mufakat maka penyelesaian dilakukan melalui proses hukum.

Pasal 17
Keadaan Kahar (*Force Majeure*)

(1) **PARA PIHAK** dibebaskan dari tanggung jawab atas keterlambatan atau kegagalan dalam memenuhi kewajiban yang dimaksud dalam Perjanjian Penugasan ini yang disebabkan atau diakibatkan oleh peristiwa atau kejadian diluar kekuasaan **PARA PIHAK** yang dapat digolongkan sebagai keadaan memaksa (*force majeure*).
(2) Peristiwa atau kejadian yang dapat digolongkan keadaan memaksa (*force majeure*) dalam Perjanjian Penugasan ini adalah bencana alam, wabah penyakit, kebakaran, perang, blokade, peledakan, sabotase, revolusi, pemberontakan, huru-hara, serta adanya tindakan pemerintah dalam bidang ekonomi dan moneter yang secara nyata berpengaruh terhadap pelaksanaan Perjanjian Penugasan ini.
(3) Apabila terjadi keadaan memaksa (*force majeure*) maka pihak yang mengalami wajib memberitahukan kepada pihak lainnya secara tertulis, selambat-lambatnya dalam waktu 7 (tujuh) hari kerja sejak terjadinya keadaan memaksa (*force majeure*), disertai dengan bukti-bukti yang sah dari pihak yang berwajib, dan **PARA PIHAK** dengan itikad baik akan segera membicarakan penyelesaiannya.

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Pasal 18
Lain-lain

(1) **PIHAK KEDUA** menjamin bahwa Penelitian dengan judul tersebut di atas belum pernah dibiayai dan/atau diikutsertakan pada Pendanaan Penelitian lainnya, baik yang diselenggarakan oleh instansi, lembaga, perusahaan atau yayasan, baik di dalam maupun di luar negeri.

(2) Segala sesuatu yang belum cukup diatur dalam Perjanjian ini dan dipandang perlu diatur lebih lanjut dan dilakukan perubahan oleh **PARA PIHAK**, maka perubahan-perubahannya akan diatur dalam perjanjian tambahan atau perubahan yang merupakan satu kesatuan dan bagian yang tidak terpisahkan dari Perjanjian ini.

Perjanjian ini dibuat dan ditandatangani oleh PARA PIHAK pada hari dan tanggal tersebut di atas, dibuat dalam rangkap 2 (dua) dan bermeterai cukup sesuai dengan ketentuan yang berlaku, yang masing-masing mempunyai kekuatan hukum yang sama.

PIHAK PERTAMA	PIHAK KEDUA
METERAI TEMPEL 3B1A9AFF827797727 6000 ENAM RIBU RUPIAH	
Dr. CHATIEF KUNJAYA, M.Sc.	Dr.Eng ROMY BUDHI, S.T, M.T
NIP: 20150008	NIDN: 0704087301

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http://www.machung.ac.id

BERITA ACARA PEMBAYARAN

Nomor : 008/BAP/P-I/MACHUNG/LPPM/2019

1. Nama : Dr. CHATIEF KUNJAYA, M.Sc.
   NIP : 20150008
   Jabatan : Rektor
   Alamat : Villa Puncak Tidar N-01 Malang

Dalam hal ini bertindak dan atas nama Universitas Ma Chung dalam Berita Acara Pembayaran ini selanjutnya disebut sebagai **PIHAK PERTAMA**.

2. Nama : Dr.Eng ROMY BUDHI, S.T, M.T
   NIDN : 0704087301
   Jabatan : Ketua Pelaksana/Dosen Universitas Ma Chung
   Alamat : Villa Puncak Tidar N-01 Malang

Dalam hal ini bertindak untuk dan atas nama Ketua Pelaksana Penelitian Tahun Jamak skim Penelitian Terapan Unggulan Perguruan Tinggi Tahun Anggaran 2019 yang selanjutnya dalam Berita Acara Pembayaran ini disebut sebagai **PIHAK KEDUA**.

A. Berdasarkan:

No. dan tanggal SP2H	:	008/MACHUNG/LPPM/SP2H-LIT-MULTI/III/2019 tanggal 27 Maret 2019
Nilai SP2H	:	**Rp131.220.000(Seratus Tiga Puluh Satu Juta Dua Ratus Dua Puluh Ribu Rupiah)**
Judul Penelitian	:	Teknologi Tepat Guna untuk Penyandang Disabilitas Lengan dalam Mengoperasikan Komputer
Uraian Pekerjaan	:	Penelitian Terapan Unggulan Perguruan Tinggi

B. Berdasarkan Surat Perjanjian Penugasan Penelitian Tahun Tunggal skim Penelitian Terapan Unggulan Perguruan Tinggi tersebut, maka **PIHAK KEDUA** berhak menerima pembayaran dari **PIHAK PERTAMA** dengan rincian sebagai berikut:

1. Pembayaran	:	Pertama 100%
2. Perhitungan Pembayaran		
a. Jumlah pembayaran fisik pada BAP ini 100%	:	Rp131.220.000
b. Jumlah pembayaran fisik pada BAP lalu	:	- (+)
c. Jumlah pembayaran fisik s.d. BAP ini	:	Rp131.220.000

PIHAK KEDUA setuju atas jumlah pembayaran tersebut di atas dan dibayarkan melalui BNI dengan nomor rekening atas nama Dr.Eng ROMY BUDHI, S.T, M.T

Berita Acara ini dibuat rangkap 2 (dua) untuk dipergunakan sesuai dengan keperluan.

PIHAK PERTAMA	**PIHAK KEDUA**
Dr. CHATIEF KUNJAYA, M.Sc.	**Dr.Eng ROMY BUDHI, S.T, M.T**
NIP. 20150008	**NIDN. 0704087301**

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KUITANSI

Sudah Terima dari	:	LPPM Universitas Ma Chung
Uang sebesar (dengan huruf)	:	**Seratus Tiga Puluh Satu Juta Dua Ratus Dua Puluh Ribu Rupiah**
Untuk Pembayaran	:	Biaya Penugasan Penelitian Tahun Jamak skim Penelitian Terapan Unggulan Perguruan Tinggi Tahun Anggaran 2019, sesuai dengan Surat Perjanjian Penugasan Penelitian Nomor: 008/MACHUNG/LPPM/SP2H-LIT-MULTI/III/2019 tanggal 27 Maret 2019.

Rp131.220.000

PIHAK PERTAMA

Dr. CHATIEF KUNJAYA, M.Sc.
NIP. 20150008

PIHAK KEDUA

Dr.Eng ROMY BUDHI, S.T, M.T
NIDN. 0704087301

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SURAT PERNYATAAN TANGGUNGJAWAB MUTLAK BERDASARKAN KONTRAK PENELITIAN TAHUN JAMAK

Yang bertanda tangan di bawah ini :

Nama	:	Dr.Eng ROMY BUDHI, S.T, M.T
Jabatan	:	Ketua Pelaksana
Skim	:	Penelitian Terapan Unggulan Perguruan Tinggi
Institusi	:	Universitas Ma Chung
Nomor SP2H	:	041/SP2H/LT/MULTI/L7/2019
Nomor SP2H Ma Chung	:	008/MACHUNG/LPPM/SP2H-LIT-MULTI/III/2019
Jumlah Dana	:	Rp131.220.000

Menyatakan dengan sesungguhnya bahwa :

1. Bertanggungiawab penuh atas pelaksanaan kegiatan Penelitian;
2. Bertanggungjawab mutlak dalam membelanjakan dana Kontrak Penelitian Tahun Jamak dan menyimpan semua bukti-bukti pengeluaran sesuai dengan jumlah dana yang diberikan;
3. Bertanggungjawab mengembalikan sisa dana yang tidak dibelanjakan ke kas Negara;
4. Bertanggungjawab untuk menindaklanjuti dan mengupayakan hasil Kontrak Penelitian Multi Years (Tahun Jamak) yang dilakukan agar terlaksana dengan efektif dan efisien serta memenuhi luaran yang dijanjikan;
5. Bertanggungjawab untuk menyerahkan *hardcopy* dan *softcopy* Laporan Kemajuan, Laporan Akhir serta Laporan Penggunaan Dana.

Malang, 27 Maret 2019
Ketua Pelaksana
Penelitian Terapan Unggulan Perguruan Tinggi

Dr.Eng ROMY BUDHI, S.T, M.T

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Direktorat Riset dan Pengabdian Masyarakat Direktorat Jenderal Riset dan Pengembangan
Kementerian Riset, Teknologi, dan Pendidikan Tinggi
Gedung BPPT II Lantai 19, Jl. MH. Thamrin No. 8 Jakarta Pusat
http://simlitabmas.ristekdikti.go.id/

LAPORAN AKHIR PENELITIAN MULTI TAHUN

ID Proposal: 7ca56d9d-c10b-4ff4-9832-5ef3568d58fe
Laporan Akhir Penelitian: tahun ke-2 dari 2 tahun

1. IDENTITAS PENELITIAN

A. JUDUL PENELITIAN

Teknologi Tepat Guna untuk Tuna Daksa Lengan dalam Mengoperasikan Komputer

B. BIDANG, TEMA, TOPIK, DAN RUMPUN BIDANG ILMU

Bidang Fokus RIRN / Bidang Unggulan Perguruan Tinggi	Tema	Topik (jika ada)	Rumpun Bidang Ilmu
Sains dan Teknologi	-	Rekayasa Teknologi Tepat Guna	Teknik Biomedika

C. KATEGORI, SKEMA, SBK, TARGET TKT DAN LAMA PENELITIAN

Kategori (Kompetitif Nasional/ Desentralisasi/ Penugasan)	Skema Penelitian	Strata (Dasar/ Terapan/ Pengembangan)	SBK (Dasar, Terapan, Pengembangan)	Target Akhir TKT	Lama Penelitian (Tahun)
Penelitian Desentralisasi	Penelitian Terapan Unggulan Perguruan Tinggi	SBK Riset Terapan	SBK Riset Terapan	6	2

2. IDENTITAS PENGUSUL

Nama, Peran	Perguruan Tinggi/ Institusi	Program Studi/ Bagian	Bidang Tugas	ID Sinta	H-Index
ROMY BUDHI Ketua Pengusul	Universitas Ma Chung	Teknik Informatika		5975211	5
MOCHAMAD SUBIANTO M.Cs Anggota Pengusul 1	Universitas Ma Chung	Teknik Informatika		167192	0
PAULUS LUCKY TIRMA IRAWAN S.Kom, M.T Anggota Pengusul 2	Universitas Ma Chung	Teknik Informatika		6153959	0

3. MITRA KERJASAMA PENELITIAN (JIKA ADA)

Pelaksanaan penelitian dapat melibatkan mitra kerjasama, yaitu mitra kerjasama dalam melaksanakan penelitian, mitra sebagai calon pengguna hasil penelitian, atau mitra investor

Mitra	Nama Mitra
Mitra Calon Pengguna	Kertaning Tyas

4. LUARAN DAN TARGET CAPAIAN

Luaran Wajib

Tahun Luaran	Jenis Luaran	Status target capaian (*accepted, published, terdaftar atau granted, atau status lainnya*)	Keterangan (*url dan nama jurnal, penerbit, url paten, keterangan sejenis lainnya*)
2	Dokumentasi hasil uji coba produk	Ada	

Luaran Tambahan

Tahun Luaran	Jenis Luaran	Status target capaian (*accepted, published, terdaftar atau granted, atau status lainnya*)	Keterangan (*url dan nama jurnal, penerbit, url paten, keterangan sejenis lainnya*)
2	Publikasi Ilmiah Jurnal Internasional	accepted/published	Journal of Engineering Science and Technology
2	Keikutsertaan dalam Seminar Internasional	sudah dilaksanakan	IEEE

5. ANGGARAN

Rencana anggaran biaya penelitian mengacu pada PMK yang berlaku dengan besaran minimum dan maksimum sebagaimana diatur pada buku Panduan Penelitian dan Pengabdian kepada Masyarakat Edisi 12.

Total RAB 2 Tahun Rp. 135,500,000

Tahun 1 Total Rp. 0

Tahun 2 Total Rp. 135,500,000

Jenis Pembelanjaan	Item	Satuan	Vol.	Biaya Satuan	Total
Analisis Data	Biaya konsumsi rapat	OH	1	250,000	250,000
Analisis Data	HR Pengolah Data	P (penelitian)	2	1,500,000	3,000,000
Bahan	ATK	Paket	2	270,000	540,000
Bahan	Bahan Penelitian (Habis Pakai)	Unit	10	950,000	9,500,000
Bahan	Barang Persediaan	Unit	20	4,380,700	87,614,000
Pelaporan, Luaran Wajib, dan Luaran Tambahan	Biaya seminar internasional	Paket	1	6,000,000	6,000,000
Pelaporan, Luaran Wajib, dan Luaran Tambahan	Publikasi artikel di Jurnal Internasional	Paket	1	7,500,000	7,500,000
Pelaporan, Luaran Wajib, dan Luaran Tambahan	Luaran KI (paten, hak cipta dll)	Paket	1	3,100,000	3,100,000
Pelaporan, Luaran Wajib,	Biaya pembuatan dokumen	Paket	1	2,000,000	2,000,000

Jenis Pembelanjaan	Item	Satuan	Vol.	Biaya Satuan	Total
dan Luaran Tambahan	uji produk				
Pengumpulan Data	Biaya konsumsi	OH	2	250,000	500,000
Pengumpulan Data	HR Sekretariat/Administrasi Peneliti	OB	5	300,000	1,500,000
Pengumpulan Data	Transport	OK (kali)	15	100,000	1,500,000
Pengumpulan Data	HR Pembantu Lapangan	OH	63	80,000	5,040,000
Pengumpulan Data	HR Petugas Survei	OH/OR	182	8,000	1,456,000
Pengumpulan Data	HR Pembantu Peneliti	OJ	240	25,000	6,000,000

6. HASIL PENELITIAN

A. RINGKASAN: Tuliskan secara ringkas latar belakang penelitian, tujuan dan tahapan metode penelitian, luaran yang ditargetkan, serta uraian TKT penelitian.

Fokus riset unggulan Universitas Ma Chung 2016-2020, salah satunya adalah Rekayasa Teknologi Tepat Guna. Penelitian Terapan ini diajukan untuk melanjutkan Penelitian Dasar mandiri yang sudah dilakukan peneliti dengan nomor kontrak (No. 001/BAPUPPM/LPPM/MANDIRI/IV/2018), yang telah menghasilkan konsep dan metode dengan level TKT 3.

Penyandang tuna daksa lengan sangatlah sulit mengoperasikan komputer baik mouse maupun keyboard. Keyboard virtual telah ada di sistem operasi Windows yang pengoperasiannya menggunakan mouse. Sehingga kunci utama supaya penyandang dapat menggunakan komputer adalah menciptakan mouse sebagai luaran teknologi tepat guna. Tahun pertama luaran yang diinginkan adalah level TKT 5, dan tahun kedua adalah TKT level 6. Penelitian dasar telah dilakukan dengan skema mandiri di tahun 2018 dan menghasilkan TKT level 3 dimana penggunaan sensor fusion telah berhasil menjadi konsep yang menghasilkan luaran sudut untuk digunakan sebagai gerakan kursor mouse; dari gerakan lengan penyandang tuna daksa. Penggunaan sensor fusion akan dikaji lebih lanjut pada penelitian ini dan diimplementasikan dengan menggunakan board elektronik terpadu sehingga luaran memiliki error yang lebih kecil dan performansi lebih baik dari hasil penelitian dasar yang menjadi landasan penelitian ini. Harapan kedepannya jika sudah berhasil diterapkan pada board elektronik terpadu maka dapat menjadi produk tepat guna bagi penyandang tuna daksa lengan.

Sampai tahun terakhir penelitian ini, luaran wajib berupa dokumen uji coba produk telah dihasilkan dan juga video uji coba produk telah diupload di youtube link: https://youtu.be/MgIsKEnYzH0 . Sedangkan luaran tambahan jurnal dan prosiding juga telah dihasilkan. Luaran tambahan tahun pertama berupa Hak Cipta Software telah berhasil didaftarkan dengan nomor pendaftaran: EC00201942276 tanggal 14 Juni 2019. TKT akhir penelitian PTUPT ini adalah level 6. Diharapkan berikutnya peneliti dapat melanjutkan ke penelitian pengembangan untuk menghasilkan produk.

B. KATA KUNCI: Tuliskan maksimal 5 kata kunci.

Sensor fusion; teknologi terapan; disabilitas; mouse; human computer interaction

Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. HASIL PELAKSANAAN PENELITIAN: Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian dapat berupa data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

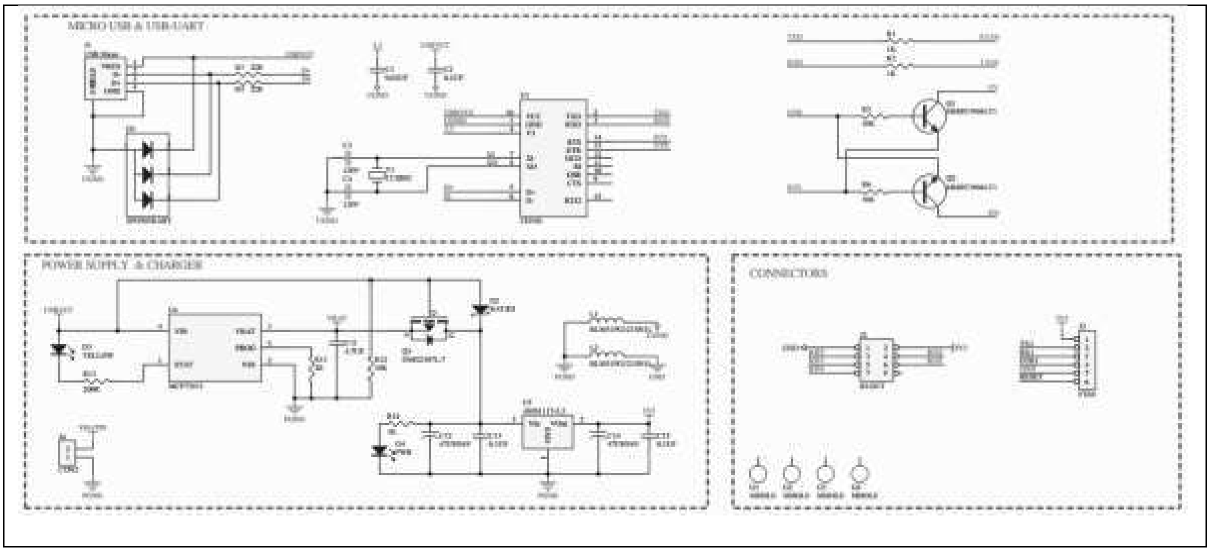
Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. **HASIL PELAKSANAAN PENELITIAN:** Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian dapat berupa data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

Tahun 2020 adalah tahun kedua dan sekaligus tahun terakhir penelitian Mouse untuk Difabel ini. Saat ini telah menghasilkan prototipe dengan level TKT 6, sesuai proposal pada saat itu. Indikator pengukuran menunjukkan 80% pada setiap item TKT meter untuk kategori Engineering: 1) Kondisi lingkungan operasi sesungguhnya telah diketahui; 2) Kebutuhan investasi untuk peralatan dan proses pabrikasi teridentifikasi; 3) M&S untuk kinerja sistem teknologi pada lingkungan operasi; 4) Bagian manufaktur/ pabrikasi menyetujui dan menerima hasil pengujian lab.; 5) Prototipe telah teruji dengan akurasi/ fidelitas lab yang tinggi pada simulasi lingkungan operasional (yang sebenarnya di luar lab); 6) Hasil Uji membuktikan layak secara teknis (engineering feasibility). Laporan akhir ini tidak berbeda jauh dengan laporan kemajuan yang kami kumpulkan pada bulan-bulan yang lalu. Ada beberapa tambahan menyangkut luaran. Berikut adalah gambar prototipe yang telah dihasilkan pada tahun kedua:

Gambar 1. Prototipe mouse untuk difabel tahun kedua

Adapun rancangan prototipe yang dihasilkan mengikuti blok diagram hasil seperti pada Gambar 2:



Gambar 2. Blok diagram prototipe mouse untuk difabel pada tahun kedua

Pada tahun kedua ini perbaikan dilakukan pada prototipe. Secara umum prototipe terdiri dari tiga blok besar yaitu Modul Wireless, Modul Sensor Inertial, dan Modul Battery.

Modul Wireless digunakan untuk mengirim data sensor ke PC. Saat ini menggunakan saluran WiFi. Percobaan dengan jalur WiFi berhasil mengirim data dari sensor ke PC. Data yang dikirim berupa roll, pitch, dan yaw posisi sensor.

Sedangkan modul sensor inertial digunakan untuk menangkap posisi/orientasi dari posisi lengan atas penyandang difabel. Orientasi tersebut akan diubah oleh PC menjadi koordinat kursor pada layar monitor. Aksi klik untuk mengemulasikan klik kiri dan klik kanan mouse dilakukan menggunakan tombol/switch di kaki (*footswitch*). Hasil klik tombol tersebut dikirim juga dengan WiFi ke PC.

Modul battery digunakan untuk memberi supply tegangan saat prototipe beroperasi. Modul ini akan di-charge saat prototipe terhubung ke PC melalui kabel micro USB.

D. **STATUS LUARAN**: Tuliskan jenis, identitas dan status ketercapaian setiap luaran wajib dan luaran tambahan (jika ada) yang dijanjikan pada tahun pelaksanaan penelitian. Jenis luaran dapat berupa publikasi, perolehan kekayaan intelektual, hasil pengujian atau luaran lainnya yang telah dijanjikan pada proposal. Uraian status luaran harus didukung dengan bukti kemajuan ketercapaian luaran sesuai dengan luaran yang dijanjikan. Lengkapi isian jenis luaran yang dijanjikan serta mengunggah bukti dokumen ketercapaian luaran wajib dan luaran tambahan melalui Simlitabmas mengikuti format sebagaimana terlihat pada bagian isian luaran

Dalam proposal direncanakan luaran Wajib dan Tambahan sebagai berikut:

Tahun Luaran	Luaran Wajib	Luaran Tambahan
Tahun 1	Purwarupa (Penerapan)	- Prosiding pertemuan ilmiah Internasional (sudah dilaksanakan) - Hak Cipta (Terdaftar)
Tahun 2	Dokumentasi hasil uji coba produk (Ada)	- Publikasi ilmiah Jurnal Internasional (submitted/accepted) - Keikutsertaan dalam Seminar

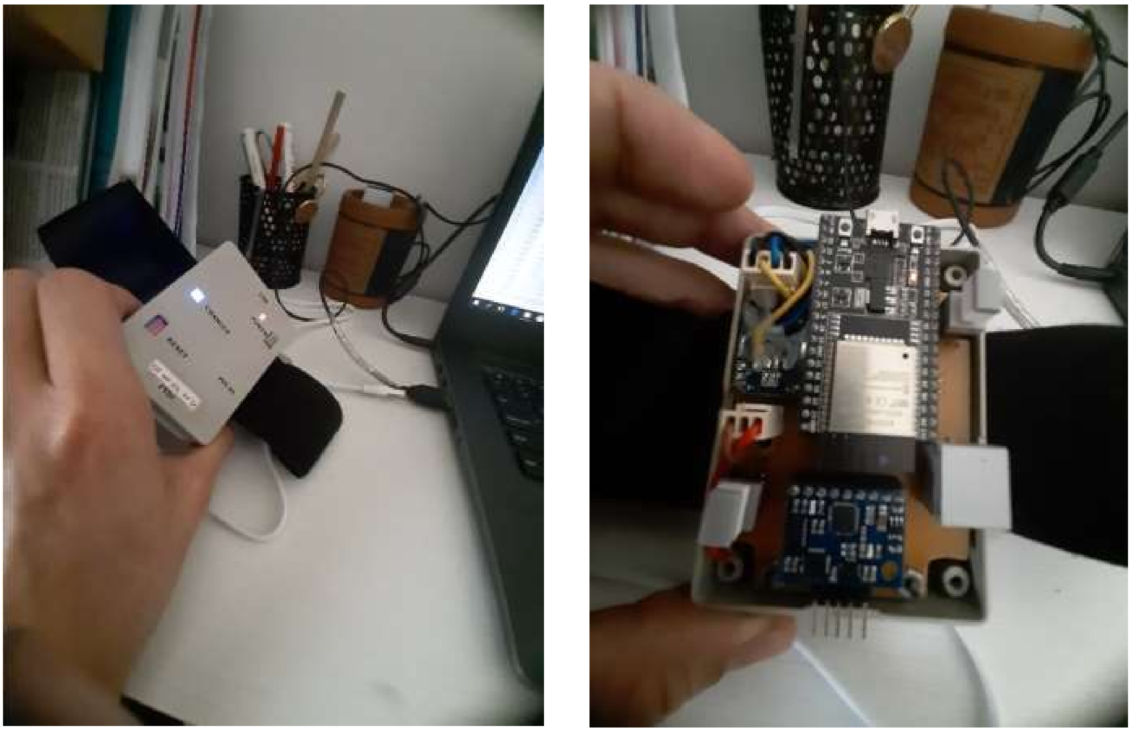
		Internasional (sudah dilaksanakan)

Berikut laporan luaran Wajib dan Tambahan tahun I dan tahun II:

A. TAHUN I (2019)

1. Purwarupa (Luaran Wajib)

Waktu itu di tahun pertama, dihasilkan prototipe dengan TKT 4. Gambar prototipe di tahun I, seperti pada Gambar 3.



Gambar 3. Prototipe mouse untuk difabel pada tahun pertama (TKT level 4)

Analisis prototipe: Secara umum prototipe terdiri dari tiga blok besar yaitu Modul Wireless, Modul Sensor Inertial, dan Modul Battery.

Modul Wireless digunakan untuk mengirim data sensor ke PC. Saat ini menggunakan saluran WiFi dan jalur bluetooth belum dicoba. Percobaan dengan jalur WiFi berhasil mengirim data dari sensor ke PC. Data yang dikirim berupa roll, pitch, dan yaw posisi sensor.

Sedangkan modul sensor inertial digunakan untuk menangkap posisi/orientasi dari posisi lengan atas penyandang difabel. Orientasi tersebut akan diubah oleh PC menjadi koordinat kursor pada layar monitor. Aksi klik untuk mengemulasikan klik kiri dan klik kanan mouse dilakukan menggunakan tombol. Hasil klik tombol tersebut dikirim juga dengan WiFi ke PC.

Modul battery digunakan untuk memberi supply tegangan saat prototipe beroperasi. Modul ini akan di-charge saat prototipe terhubung ke PC melalui kabel micro USB.

2. Prosiding pertemuan ilmiah Internasional (Sudah dilaksanakan-Luaran Tambahan)

Prosiding pertemuan ilmiah telah dilaksanakan bulan Agustus 2019 di International Conference ISITIA-ITS Surabaya.

Judul artikel : The IMU and Bend Sensor as a Pointing Device and Click Method
Penulis : Romy Budhi Widodo, Agustinus Bohaswara Haryasena, Hendry Setiawan, Moch. Subianto, Paulus Lucky T. Irawan.
Nama conference: 2019 International Seminar on Intelligent Technology and Its Applications (ISITIA)
Penyelenggara : ITS Surabaya
DOI : 10.1109/ISITIA.2019.8937086
Website : https://ieeexplore.ieee.org/document/8937086

3. Hak Cipta (Terdaftar-Luaran Tambahan)

Hak Cipta software pengukuran Multitasking dengan nomor pendaftaran: EC00201942276 tanggal 14 Juni 2019.


REPUBLIK INDONESIA
KEMENTERIAN HUKUM DAN HAK ASASI MANUSIA

SURAT PENCATATAN CIPTAAN

Dalam rangka pelindungan ciptaan di bidang ilmu pengetahuan, seni dan sastra berdasarkan Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta, dengan ini menerangkan:

Nomor dan tanggal permohonan	:	EC00201942276, 14 Juni 2019
Pencipta		
Nama	:	**Dr. Eng. Romy Budhi Widodo**
Alamat	:	Jl. Diponegoro 12, Gotanyo, Karangploso, Malang, Jawa Timur, -
Kewarganegaraan	:	Indonesia
Pemegang Hak Cipta		
Nama	:	**Universitas Ma Chung**
Alamat	:	Villa Puncak Tidar N-01, Malang, Jawa Timur, 65151
Kewarganegaraan	:	Indonesia
Jenis Ciptaan	:	**Program Komputer**
Judul Ciptaan	:	**Multi Direction Test**
Tanggal dan tempat diumumkan untuk pertama kali di wilayah Indonesia atau di luar wilayah Indonesia	:	7 Juni 2019, di Malang
Jangka waktu pelindungan	:	Berlaku selama 50 (lima puluh) tahun sejak Ciptaan tersebut pertama kali dilakukan Pengumuman.
Nomor pencatatan	:	000144870

adalah benar berdasarkan keterangan yang diberikan oleh Pemohon.
Surat Pencatatan Hak Cipta atau produk Hak terkait ini sesuai dengan Pasal 72 Undang-Undang Nomor 28 Tahun 2014 tentang Hak Cipta.

a.n. MENTERI HUKUM DAN HAK ASASI MANUSIA
DIREKTUR JENDERAL KEKAYAAN INTELEKTUAL

Dr. Freddy Harris, S.H., LL.M., ACCS.
NIP. 196611181994031001

Gambar 4. Sertifikat KI software pengukuran Multitasking

B. TAHUN II (2020)

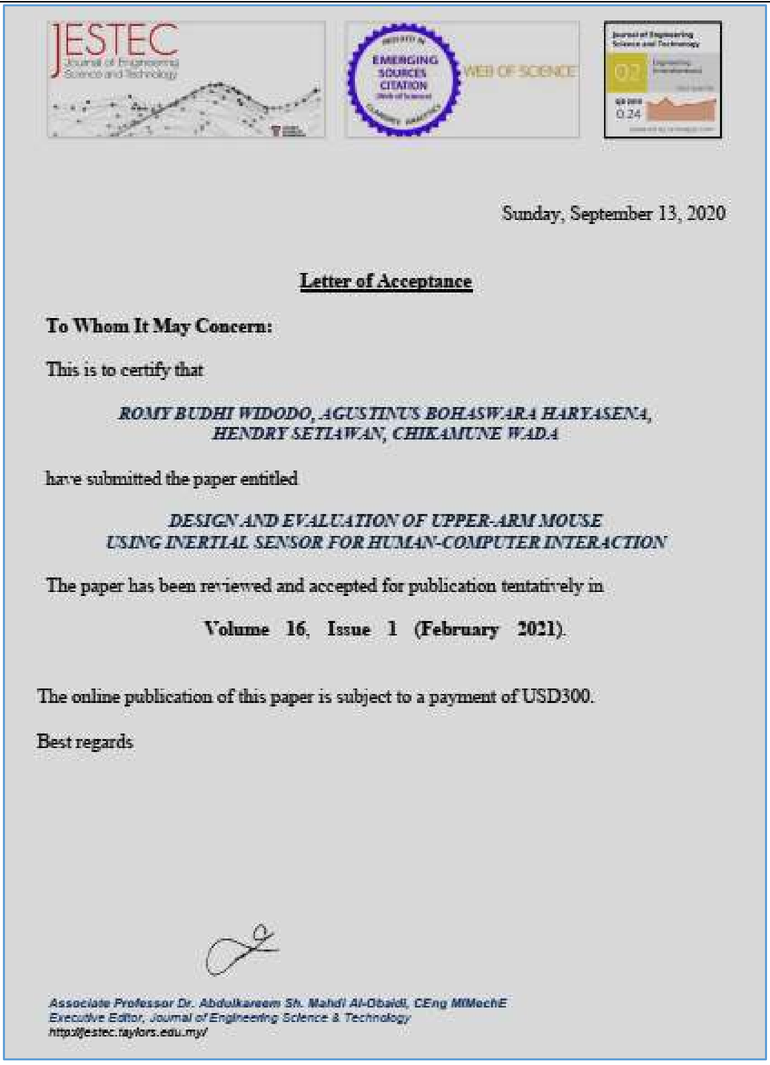
1. Dokumentasi Hasil Uji Coba Produk (Ada-Luaran Wajib)

Dokumentasi hasil uji coba produk telah dihasilkan di akhir tahun II ini. Dokumen pdf telah diupload dalam laman simlitabmas. Sedangkan video dokumentasi uji coba produk diupload pada: https://youtu.be/MgIsKEnYzH0

2. Publikasi ilmiah Jurnal Internasional (Submitted/accepted-Luaran Tambahan)

Judul : Design and Evaluation of Upper Arm Mouse for Pointing Device
Penulis : Romy Budhi Widodo; Agustinus Bohaswara Haryasena; Mochamad Subianto; Paulus Lucky T. Irawan, Hendry Setiawan; Chikamune Wada
Nama Jurnal : Journal of Engineering Science and Technology / JESTEC
Penyelenggara : Taylor's University Malaysia
ISSN : 1823-4690
Vol. No : **Volume: 15, Issue: 6- Desember 2020**
Website : http://jestec.taylors.edu.my/V15Issue6.htm
Status : **Published**

Gambar 5 menunjukkan surat penerimaan dari Editorial jurnal. Namun saat ini sudah di Publish di **http://jestec.taylors.edu.my/V15Issue6.htm**



JESTEC Journal of Engineering Science and Technology

Sunday, September 13, 2020

Letter of Acceptance

To Whom It May Concern:

This is to certify that

ROMY BUDHI WIDODO, AGUSTINUS BOHASWARA HARYASENA, HENDRY SETIAWAN, CHIKAMUNE WADA

have submitted the paper entitled

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

The paper has been reviewed and accepted for publication tentatively in

Volume 16, Issue 1 (February 2021).

The online publication of this paper is subject to a payment of USD300.

Best regards

Associate Professor Dr. Abdulkareem Sh. Mahdi Al-Obaidi, CEng MIMechE
Executive Editor, Journal of Engineering Science & Technology
http://jestec.taylors.edu.my/

Gambar 5. Surat Accepted dari Editorial jurnal

3. Keikutsertaan dalam Seminar Internasional (sudah dilaksanakan-Luaran Tambahan)

Judul artikel : The Combination of Foot Switch and Low-Cost IMU for a Wearable Mouse in Human-computer Interaction
Penulis : Romy Budhi Widodo, Evans Jahja, Yusuf Giovanno
Nama conference: ICITEE 2020- The 12th International Conference on Information Technology and Electrical Engineering
Tanggal pelaksanaan virtual: 6-8 Oktober 2020
Penyelenggara : Department of Electrical and Information Engineering, Universitas Gadjah Mada
DOI : belum keluar dari penyelenggara (masih proses)
Website : IEEEXPLORE-masih proses (https://icitee.ugm.ac.id/)

Gambar 6 merupakan sertifikat presenter dari kegiatan International Conference tersebut.


UNIVERSITAS GADJAH MADA

CERTIFICATE

This certificate is awarded to

Romy Budhi Widodo

Ma Chung University, Indonesia

in recognition of invaluable support and participation in

Joint Conference 2020

held on October 6th-8th 2020, organized by Department of Electrical and Information Engineering, Faculty of Engineering, Universitas Gadjah Mada, Indonesia, as

presenter

Yogyakarta, 8th October 2020

Vice Head of Department	General Chair
Hanung Adi Nugroho, S.T., M.E., Ph.D., IPM.	Sigit Basuki Wibowo, S.T., M.Eng., Ph.D., IPM.

Gambar 6. Sertifikat pemakalah dalam International Conference

E. **PERAN MITRA:** Tuliskan realisasi kerjasama dan kontribusi Mitra baik *in-kind* maupun *in-cash* (jika ada). Bukti pendukung realisasi kerjasama dan realisasi kontribusi mitra dilaporkan sesuai dengan kondisi yang sebenarnya. Bukti dokumen realisasi kerjasama dengan Mitra diunggah melalui Simlitabmas mengikuti format sebagaimana terlihat pada bagian isian mitra

Penelitian terapan ini bermitra dengan Lingkar Sosial Malang, suatu lembaga yang bekerja sama dengan kelompok-kelompok kerja difabel di kota dan kabupaten Malang. Bentuk kerjasama adalah in kind. Berupa konsultasi ke mitra dan mitra juga memberikan saran sehingga salah satu anggotanya yang menyandang difabel lengan bawah bersedia menjadi salah satu subjek dan tempat konsultasi saat pembuatan prototipe ini.

Bentuk kerjasama di tahun kedua adalah mitra membantu partisipan difabel yang menguji coba prototipe. Peran mitra juga menjadi tempat bertukar pikiran untuk mengembangkan kerjasama dalam merintis pembuatan alat-alat yang dapat membantu difabel. Pada bulan September 2020, mitra juga bersedia bekerjasama dengan Universitas dan tertuang dalam Memorandum of Understanding (MoU).

Gambar 7 menunjukkan salah satu kegiatan dengan difabel lengan bawah pada saat menjadi subjek dalam pengujian prototipe di tahun kedua ini.

Gambar 7. Partisipan/subjek tuna daksa saat melakukan uji coba prototipe di tahun I dan II

F. **KENDALA PELAKSANAAN PENELITIAN**: Tuliskan kesulitan atau hambatan yang dihadapi selama melakukan penelitian dan mencapai luaran yang dijanjikan, termasuk penjelasan jika pelaksanaan penelitian dan luaran penelitian tidak sesuai dengan yang direncanakan atau dijanjikan.

Adanya pandemic Covid-19 di tahun ini, sedikit banyak memberi pengaruh pada penelitian ini. Pada saat uji coba prototipe, tidak bisa meluas dengan subyek difabel tuna daksa. Sehingga uji coba dikombinasikan juga dengan partisipan non-difabel. Akan tetapi puji syukur kehadirat Tuhan YME, bahwa sampai saat ini luaran-luaran masih dapat dipenuhi semua dan penelitian ini sudah selesai tahun terakhir. Semoga kita semua diberi rahmat kesehatan melalui pandemi Covid-19.

G. **RENCANA TINDAK LANJUT PENELITIAN:** Tuliskan dan uraikan rencana tindaklanjut penelitian selanjutnya dengan melihat hasil penelitian yang telah diperoleh. Jika ada target yang belum diselesaikan pada akhir tahun pelaksanaan penelitian, pada bagian ini dapat dituliskan rencana penyelesaian target yang belum tercapai tersebut.

Pada akhir penelitian ini, semua target telah terpenuhi. Sehingga rencana tindak lanjut adalah mengembangkan prototipe ini menjadi penelitian pengembangan dengan harapan suatu kelak nanti menjadi produk inovatif yang bermanfaat bagi seluruh difabel. Memberi nilai tambah bagi kehidupan sosial difabel, harapannya penyandang difabel dapat mengendalikan komputer dengan normal dan membuka lapangan kerja buat difabel.

H. DAFTAR PUSTAKA: Penyusunan Daftar Pustaka berdasarkan sistem nomor sesuai dengan urutan pengutipan. Hanya pustaka yang disitasi pada laporan akhir yang dicantumkan dalam Daftar Pustaka.

1. R.B. Widodo, 2018, "Analisis Gerakan Orientasi pada Kaji Awal Mouse bagi Penyandang Disabilitas," Prosiding Seminar dan Konferensi Nasional IDEC, UNS, Surakarta, pp. 52-57
2. R.B. Widodo, H. Edayoshi, and C. Wada, 2014, "Complementary filter for orientation: Adaptive gain based on dynamic acceleration and its change," 7th Int.Conf. on Soft Computing and Intelligent Systems, SCIS and 15th Int. Symposium on Advanced Intelligent Systems, ISIS, pp. 906–909
3. R.B. Widodo and C. Wada, 2016, “Attitude Estimation Using Kalman Filtering: External Acceleration Compensation Considerations,” Journal of Sensors, Vol. 2016, Article ID 6943040, 24 pages. doi:10.1155/2016/6943040
4. R.B. Widodo, R.M. Quita, Suherman, and C. Wada, 2019, “A study of hand-movement gestures to substitute for mouse-cursor placement using an inertial sensor,” *Journal of Sensors and Sensor Systems*, Vol. 8.
5. R.B. Widodo, A.Haryasena, H. Setiawan, M. Subianto, and P.L. Irawan, 2019, “*The IMU and Bend Sensor as a Pointing Device and Click Method*”, International Seminar on Intelligent Technology and Its Applications (ISITIA), pp. 306-309. (https://ieeexplore.ieee.org/document/8937086)
6. R.B. Widodo, A.Haryasena, H. Setiawan, and C. Wada, 2021, “Design and Evaluation of Upper-Arm Mouse using Inertial Sensor for Human-Computer Interaction,” Journal of Engineering Science and Technology, Vol. 16 (1), (in press)

Dokumen pendukung luaran Wajib #1

Luaran dijanjikan: Dokumentasi hasil uji coba produk

Target: Ada
Dicapai: Tersedia

Dokumen wajib diunggah:
1. Dokumentasi (foto) Pengujian Produk
2. Dokumen Deskripsi dan Spesifikasi Produk
3. Dokumen Hasil Uji Coba Produk

Dokumen sudah diunggah:
1. Dokumen Deskripsi dan Spesifikasi Produk
2. Dokumen Hasil Uji Coba Produk
3. Dokumentasi (foto) Pengujian Produk

Dokumen belum diunggah:
- Sudah lengkap

Nama Produk: Teknologi Tepat Guna untuk Tuna Daksa Lengan dalam Mengoperasikan Komputer
Tgl. Pengujian: 29 Oktober 2020
Link Dokumentasi: https://youtu.be/MgIsKEnYzH0

Deskripsi dan spesifikasi purwarupa produk (Luaran Wajib, PTUPT Tahun Jamak, Tahun Kedua)

Deskripsi Produk

Purwarupa dengan judul mouse untuk tuna daksa lengan ini bertujuan untuk pengganti mouse bagi orang yang membutuhkan, misalnya:

1. Penderita akibat kecelakaan yang harus istirahat di tempat tidur (*bedridden patient*)
2. Difabel lengan bawah (*forearm*) dan tangan (*hand*), akibat bawaan sejak lahir; sehingga menggunakan lengan atas (*upper arm*) sebagai penggerak utamanya.

Purwarupa ini disebut sebagai Mouse lengan atas (*upper-arm mouse*).

Invensi ini khususnya berhubungan dengan sebuah alat siap pakai di lengan atas yang dipakaikan kepada difabel yang hanya memiliki lengan atas saja yang masih berfungsi, dengan alat tersebut pemakainya dapat menggerakkan kursor mouse pada monitor komputer berdasarkan orientasi dari lengan atas.

Pada dasarnya orientasi adalah suatu istilah yang dipakai di dunia penerbangan untuk menggambarkan gerakan terhadap tiga sumbu dalam ruang tiga dimensi. Dalam ruang tiga dimensi ada sumbu X, Y, dan Z. Rotasi pada sumbu X dinamakan *Roll*, rotasi pada sumbu Y dinamakan *Pitch*, dan rotasi pada sumbu Z dinamakan *Yaw*. Ketiga sumbu ini menghasilkan bidang XY, bidang XZ dan bidang YZ.

Sedangkan tubuh manusia juga dapat dipandang dari tiga buah bidang (*plane*), yaitu *sagittal plane* (bidang sagittal)*, coronal plane* (bidang koronal), dan *horizontal/axial plane* (bidang horisontal). 1) Bidang sagittal membagi tubuh menjadi kanan (dekstra) dan kiri (sinistra), gerakan lengan atas dilihat dari bidang sagittal adalah *vertical flexion* dan *vertical extension*, 2) Bidang koronal membagi tubuh menjadi bagian tubuh depan (anterior) dan belakang (posterior), gerakan lengan atas dilihat dari bidang koronal adalah *abduction* dan *adduction*, 3) Bidang horisontal membagi tubuh menjadi bagian tubuh atas (superior) dan bawah (inferior), gerakan lengan atas dilihat dari bidang horisontal adalah *horizontal flexion* dan *horizontal extension*.

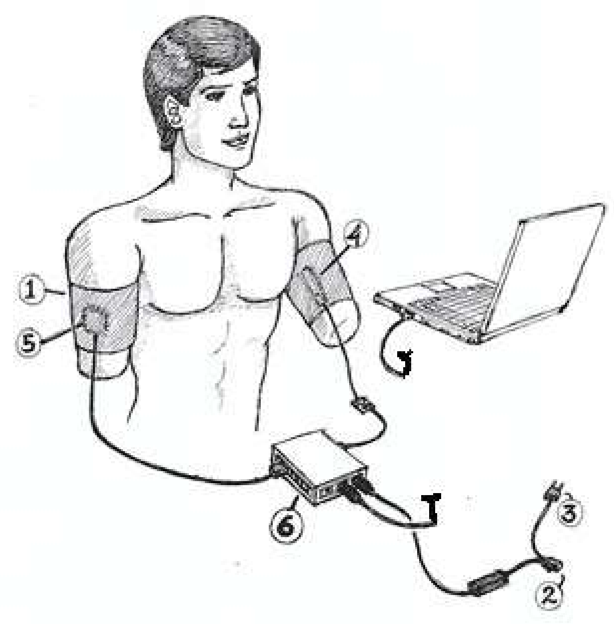
Peran *mouse* sebagai *pointing device* tidak selalu dapat digunakan oleh pengguna yang sedang mengalami beberapa gangguan diantaranya:

- tidak dapat menggunakan jari, pergelangan tangan akibat kecelakaan atau sakit, kehilangan permanen maupun kehilangan bagian lengan bawah,
- gangguan pada beberapa jari tangan yang tidak memungkinkan melakukan *grasping* (posisi menggenggam),
- kelainan kongenital (kelainan pada waktu lahir) pada jari-jari tangan dan lengan bawah.

Sehingga diperlukan pengganti *pointing device* yang sifatnya dapat digunakan permanen maupun sementara bagi pengguna yang mengalami salah satu dari gangguan-gangguan tersebut. Pengguna yang menggantungkan pekerjaan dan aktifitasnya dengan komputer sebagai sarana kerja tetap dapat mengoperasikan komputer sehingga produktifitas tidak terhenti.

Untuk mengatasi masalah di atas peneliti menciptakan alat yang menggunakan sensor-sensor orientasi yang dipasang pada lengan atas. Alat dan software pengolah datanya adalah satu kesatuan untuk difungsikan sebagai mouse bagi difabel.

Desain posisi penggunaan purwarupa:



Posisi penggunaan purwarupa yaitu di lengan bagian atas.

Ide dari *upper-arm mouse* telah didaftarkan paten:

1. Tanggal pengajuan: 29 November 2017;
   Nomor permohonan: PID201708577
   Judul invensi: Mouse untuk Difabel Lengan Bawah dan Tangan
   Kemudian tahun 2020, diajukan pemeriksaan substantive.

2. Pengajuan pemeriksaan substantif permohonan paten

   Nomor permohonan: PID201708577

   Kode Billing: 820200626456881

   Status proses: dalam antrian

Desain prototipe yang terdiri atas 3 bagian, yaitu:

1. Bagian Sensor

   Terdiri atas sensor inertial, berisi: gyro, accelerometer, dan magnetometer.

2. Bagian Transmisi Data

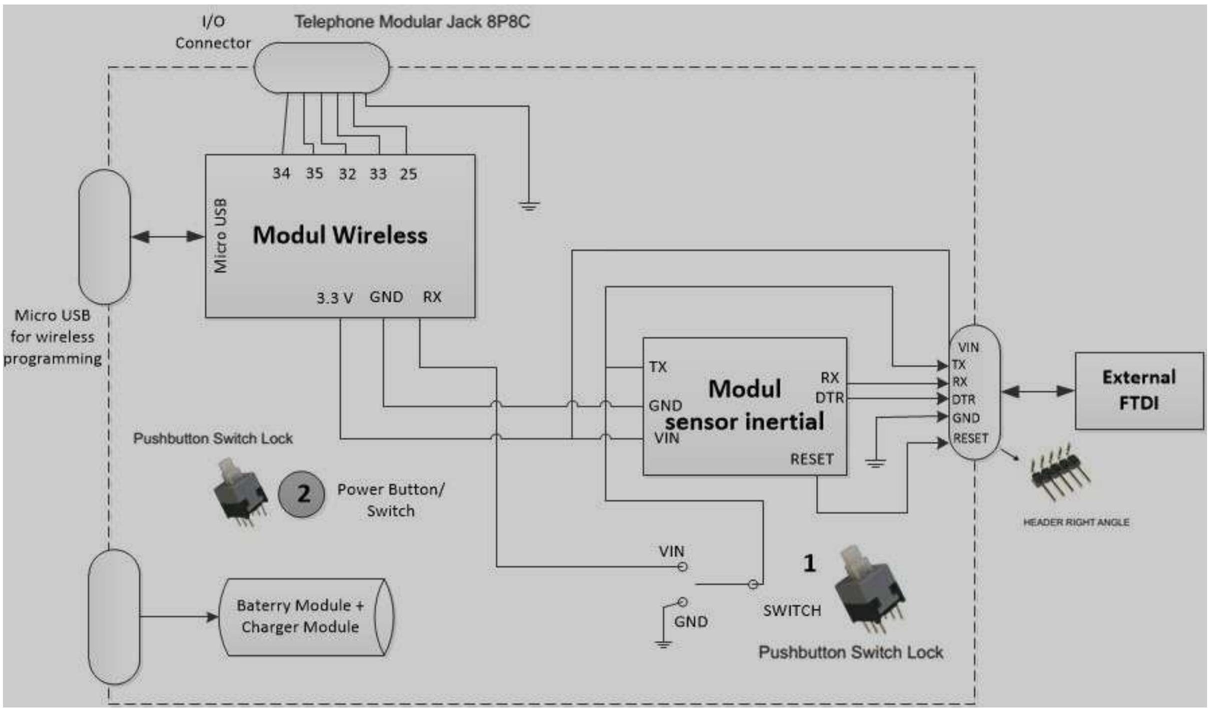
   Saat ini transmisi data menggunakan WiFi, data dari sensor dikirim ke PC tanpa menggunakan kabel.

3. Bagian Charger (Battery unit)

   Bagian ini bertugas menyediakan power supply saat purwarupa tidak terhubung ke PC. Namun saat kabel USB terhubung antara PC dan purwarupa, maka unit ini akan charge secara otomatis.

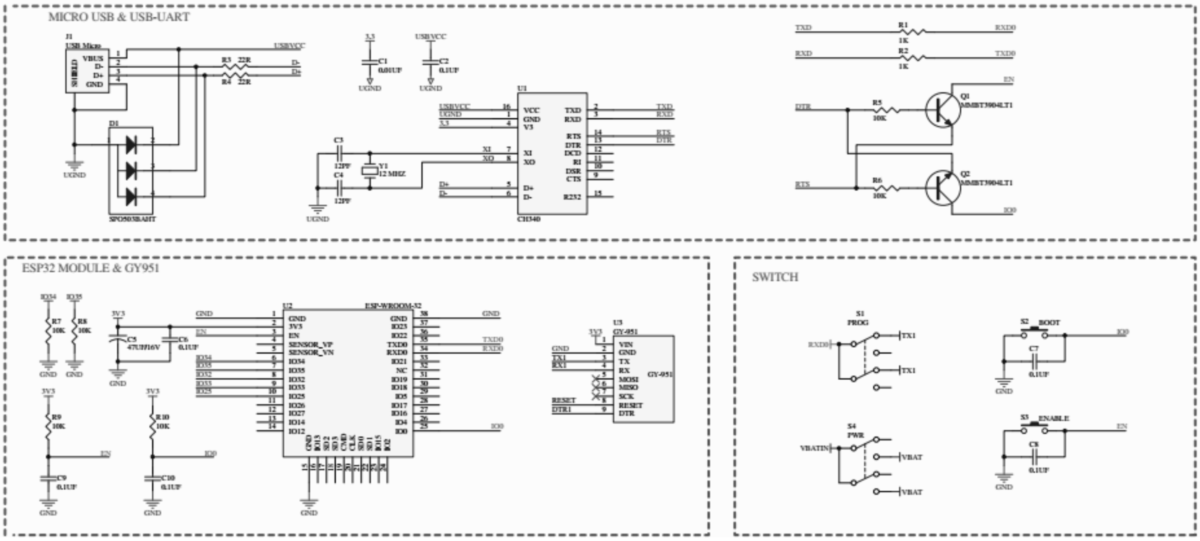
   Adapun gambar revisi tahun kedua PTUPT 2020 ini diperoleh dari hasil perbaikan tahun pertama (2019) dari ketiga blok diagram dari purwarupa adalah sebagai berikut:

   Skema 2019:



Gambar 1. Blok diagram dan skematik tahun 2019.

Skema akhir 2020:



Gambar 2. Blok diagram dan skematik perbaikan tahun 2020.

Spesifikasi

Ketiga bagian dalam purwarupa tersebut memiliki spesifikasi:

1. Sensor Inertial

Jangkauan Roll	-180^o sampai 180^o
Jangkauan Pitch	-90^o sampai 90^o
Resolusi	
Kontroler	Atmega328
Voltage	3.3VDC
Data	UART
Komponen dasar: Accelerometer Gyroscope Magnetometer	 ADXL345 ITG3200 HMC5883L

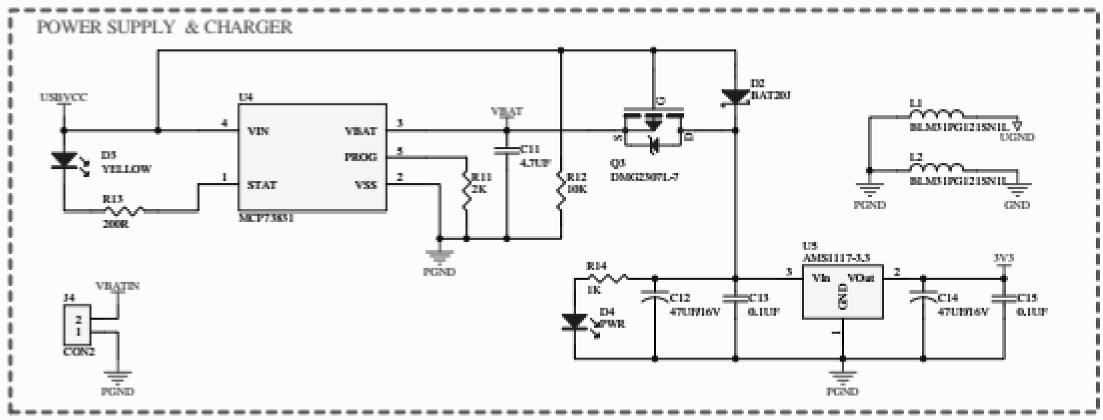
2. Modul Wireless

Fitur WiFi	802.11 b/g/n Automatic beacon monitoring 4 x virtual Wi-Fi interface
CPU	Xtensa single/dual core 32 bit 448 KB ROM, 520 KB SRAM, 16 KB

	SRAM in RTC
Clock dan Timer	Internal 8 MHz oscillator Internal RC oscillator One RTC timer, RTC watchdog

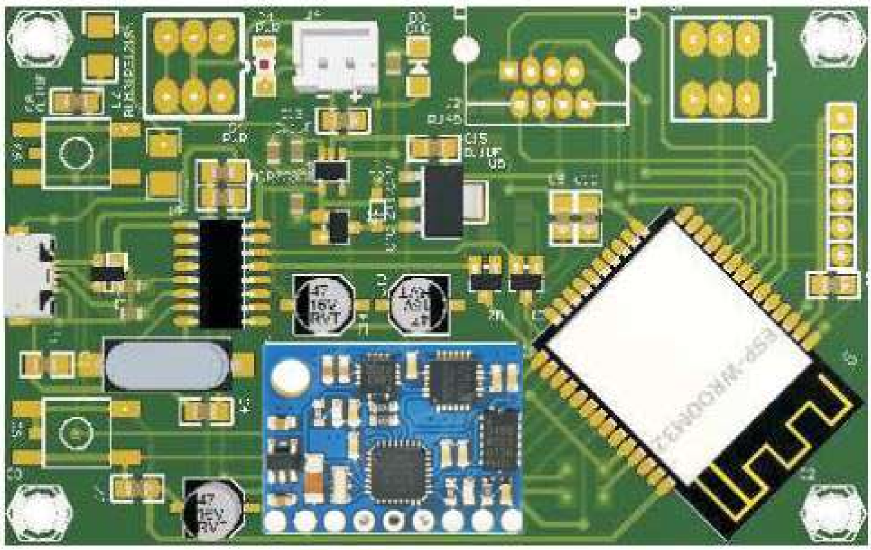
3. Modul Battery

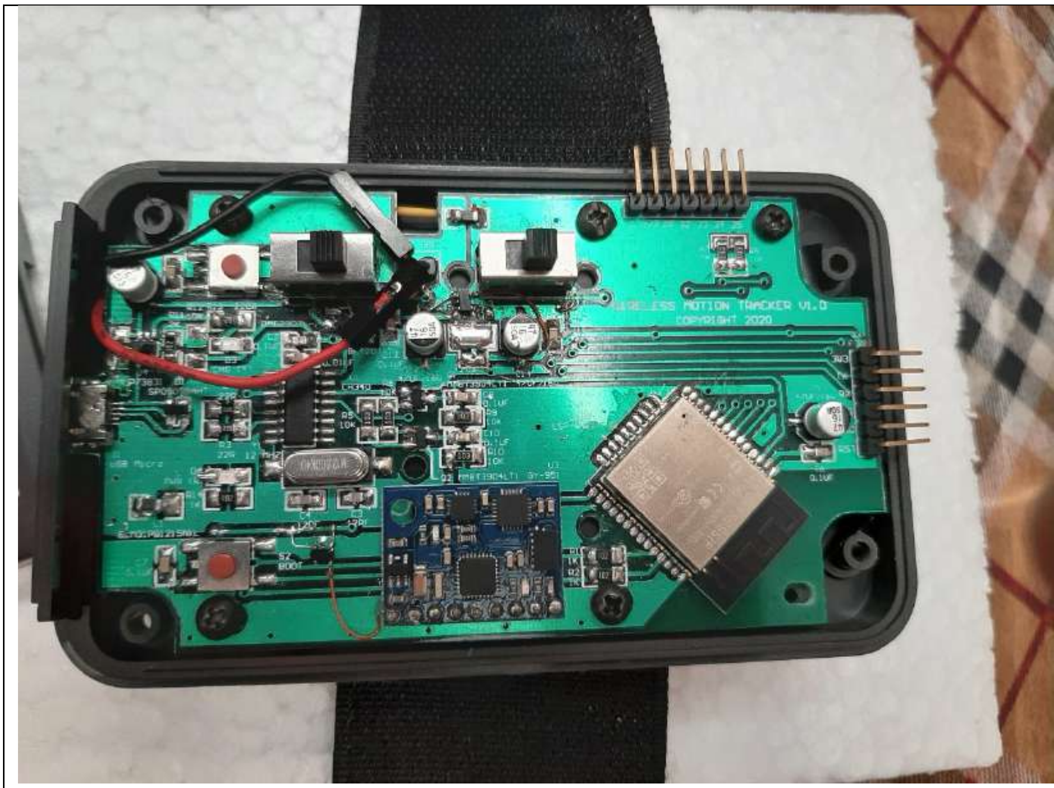
   Battery LiIon 4.7V dan regulator, dengan skematik sebagai berikut:



Gambar 3. Blok diagram dan skematik bagian catudaya tahun 2020.

Pada tahun terakhir penelitian ini telah dibuat desain PCB yang lebih kompak dan berukuran kecil, dengan memuat transmisi wifi disertai desain cover.





Gambar 4. Desain PCB dan hasil prototipe tahun 2020.

DOKUMEN UJI COBA PRODUK

PROTOTIPE TEKNOLOGI TEPAT GUNA UNTUK PENYANDANG DISABILITAS LENGAN DALAM MENGOPERASIKAN KOMPUTER

OKTOBER 2020

[COMPANY NAME]
[Company address]

Table of Contents

Dokumen hasil uji coba produk
(PTUPT Tahun Jamak, Tahun Kedua/terakhir)
Judul: "Teknologi Tepat Guna Mouse untuk Difabel"

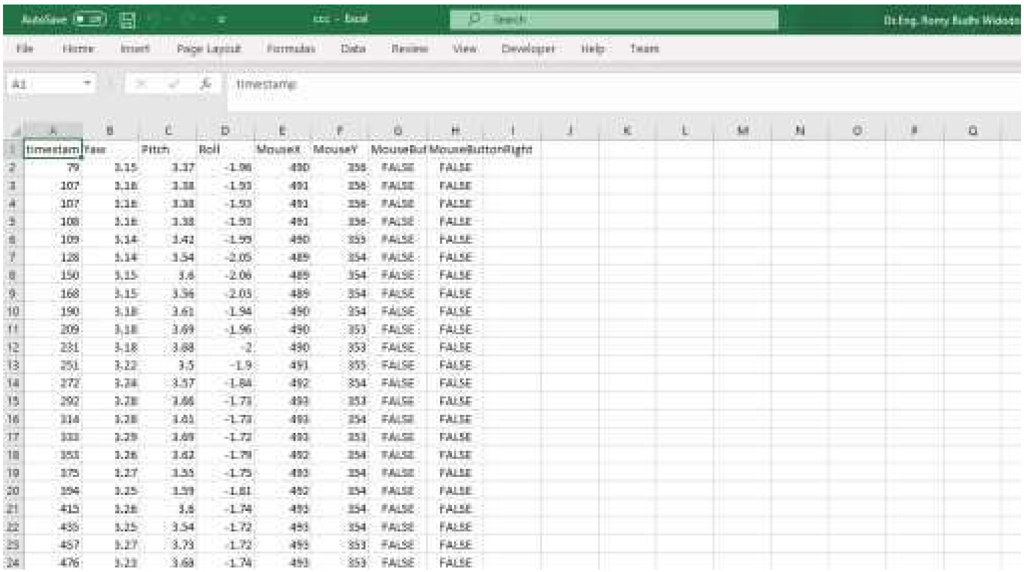
I. Pengujian Single terhadap sensor

Berikut disampaikan hasil uji coba prototipe menggunakan perangkat lunak berbasis C#. Data diperoleh dari file .csv yang disimpan ke dalam harddisk oleh software saat eksperimen berlangsung.

Langkah-langkah percobaan:

1. Mempersiapkan perangkat lunak untuk menerima transmisi Wi-Fi dari sensor (purwarupa).
2. Purwarupa telah dipasang terlebih dahulu pada lengan, atau sekedar dipegang tangan supaya dapat digerakkan miring kanan-kiri (gerakan *roll*), maupun condong ke depan-belakang (gerakan *pitch*).
3. Memulai percobaan.
4. Software akan merekam gerakan tangan termasuk kemiringan dan kecondongan sensor.
5. Data yang disimpan dalam bentuk file .csv dapat dipakai untuk analisis data.

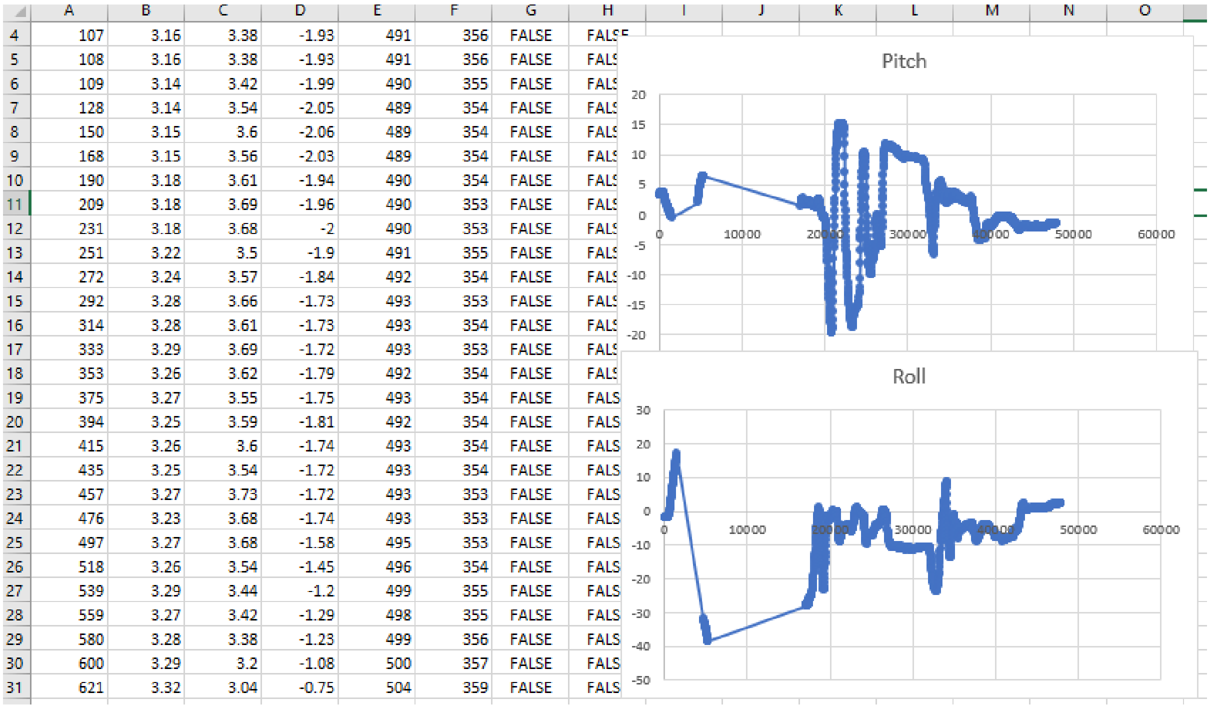
Berikut contoh data hasil .csv file:



	A	B	C	D	E	F	G	H
1	timestam	Yaw	Pitch	Roll	MouseX	MouseY	MouseBut	MouseButtonRight
2	79	3.15	3.37	-1.96	490	356	FALSE	FALSE
3	107	3.16	3.38	-1.93	491	356	FALSE	FALSE
4	107	3.16	3.38	-1.93	491	356	FALSE	FALSE
5	108	3.16	3.38	-1.93	491	356	FALSE	FALSE
6	109	3.14	3.42	-1.99	490	355	FALSE	FALSE
7	128	3.14	3.54	-2.05	489	354	FALSE	FALSE
8	150	3.15	3.6	-2.06	489	354	FALSE	FALSE
9	168	3.15	3.56	-2.03	489	354	FALSE	FALSE
10	190	3.18	3.61	-1.94	490	354	FALSE	FALSE
11	209	3.18	3.69	-1.96	490	353	FALSE	FALSE
12	231	3.18	3.68	-2	490	353	FALSE	FALSE
13	251	3.22	3.5	-1.9	491	355	FALSE	FALSE
14	272	3.24	3.57	-1.84	492	354	FALSE	FALSE
15	292	3.28	3.66	-1.73	493	353	FALSE	FALSE
16	314	3.28	3.61	-1.73	493	354	FALSE	FALSE
17	333	3.29	3.69	-1.72	493	353	FALSE	FALSE
18	353	3.26	3.62	-1.79	492	354	FALSE	FALSE
19	375	3.27	3.55	-1.75	493	354	FALSE	FALSE
20	394	3.25	3.59	-1.81	492	354	FALSE	FALSE
21	415	3.26	3.6	-1.74	493	354	FALSE	FALSE
22	435	3.25	3.54	-1.72	493	354	FALSE	FALSE
23	457	3.27	3.73	-1.72	493	353	FALSE	FALSE
24	476	3.23	3.68	-1.74	493	353	FALSE	FALSE

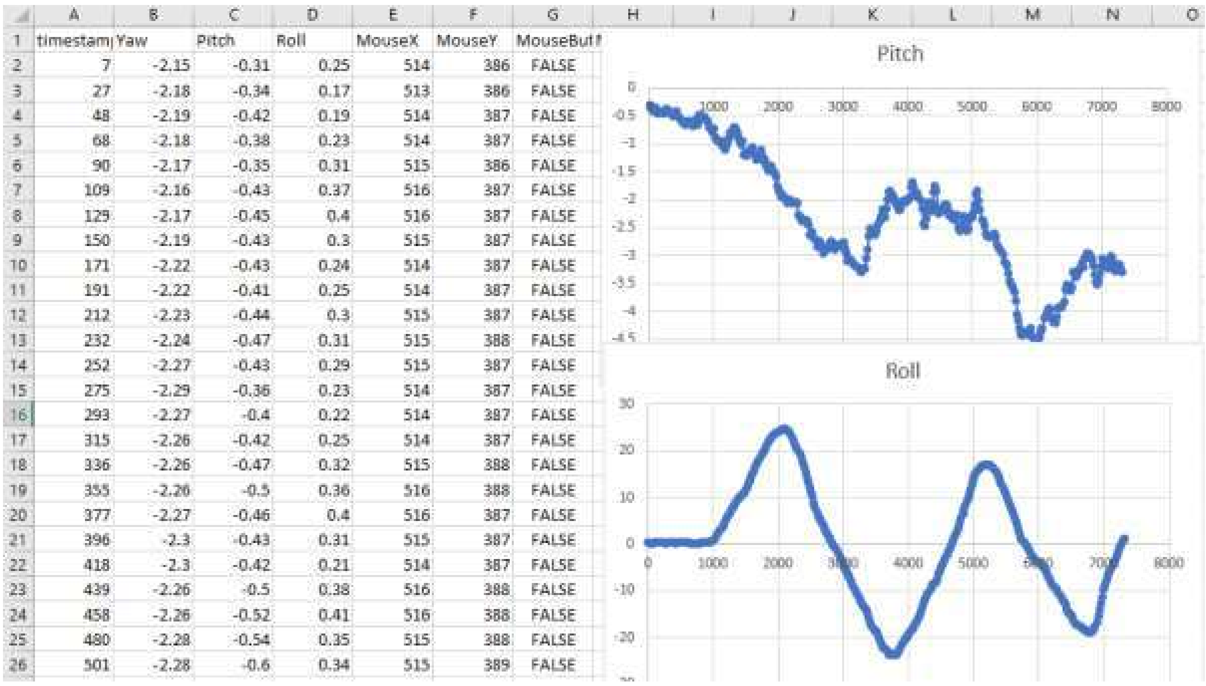
Gambar 1. Contoh bentuk tampilan luaran software, file .csv

Hasil plotting dari file .csv tersebut adalah sebagai berikut:



	A	B	C	D	E	F	G	H
4	107	3.16	3.38	-1.93	491	356	FALSE	FALSE
5	108	3.16	3.38	-1.93	491	356	FALSE	FALS
6	109	3.14	3.42	-1.99	490	355	FALSE	FALS
7	128	3.14	3.54	-2.05	489	354	FALSE	FALS
8	150	3.15	3.6	-2.06	489	354	FALSE	FALS
9	168	3.15	3.56	-2.03	489	354	FALSE	FALS
10	190	3.18	3.61	-1.94	490	354	FALSE	FALS
11	209	3.18	3.69	-1.96	490	353	FALSE	FALS
12	231	3.18	3.68	-2	490	353	FALSE	FALS
13	251	3.22	3.5	-1.9	491	355	FALSE	FALS
14	272	3.24	3.57	-1.84	492	354	FALSE	FALS
15	292	3.28	3.66	-1.73	493	353	FALSE	FALS
16	314	3.28	3.61	-1.73	493	354	FALSE	FALS
17	333	3.29	3.69	-1.72	493	353	FALSE	FALS
18	353	3.26	3.62	-1.79	492	354	FALSE	FALS
19	375	3.27	3.55	-1.75	493	354	FALSE	FALS
20	394	3.25	3.59	-1.81	492	354	FALSE	FALS
21	415	3.26	3.6	-1.74	493	354	FALSE	FALS
22	435	3.25	3.54	-1.72	493	354	FALSE	FALS
23	457	3.27	3.73	-1.72	493	353	FALSE	FALS
24	476	3.23	3.68	-1.74	493	353	FALSE	FALS
25	497	3.27	3.68	-1.58	495	353	FALSE	FALS
26	518	3.26	3.54	-1.45	496	354	FALSE	FALS
27	539	3.29	3.44	-1.2	499	355	FALSE	FALS
28	559	3.27	3.42	-1.29	498	355	FALSE	FALS
29	580	3.28	3.38	-1.23	499	356	FALSE	FALS
30	600	3.29	3.2	-1.08	500	357	FALSE	FALS
31	621	3.32	3.04	-0.75	504	359	FALSE	FALS

Gambar 2. Hasil plotting Roll dan Pitch dari .csv file



	A	B	C	D	E	F	G
1	timestam	Yaw	Pitch	Roll	MouseX	MouseY	MouseBut
2	7	-2.15	-0.31	0.25	514	386	FALSE
3	27	-2.18	-0.34	0.17	513	386	FALSE
4	48	-2.19	-0.42	0.19	514	387	FALSE
5	68	-2.18	-0.38	0.23	514	387	FALSE
6	90	-2.17	-0.35	0.31	515	386	FALSE
7	109	-2.16	-0.43	0.37	516	387	FALSE
8	129	-2.17	-0.45	0.4	516	387	FALSE
9	150	-2.19	-0.43	0.3	515	387	FALSE
10	171	-2.22	-0.43	0.24	514	387	FALSE
11	191	-2.22	-0.41	0.25	514	387	FALSE
12	212	-2.23	-0.44	0.3	515	387	FALSE
13	232	-2.24	-0.47	0.31	515	388	FALSE
14	252	-2.27	-0.43	0.29	515	387	FALSE
15	275	-2.29	-0.36	0.23	514	387	FALSE
16	293	-2.27	-0.4	0.22	514	387	FALSE
17	315	-2.26	-0.42	0.25	514	387	FALSE
18	336	-2.26	-0.47	0.32	515	388	FALSE
19	355	-2.26	-0.5	0.36	516	388	FALSE
20	377	-2.27	-0.46	0.4	516	387	FALSE
21	396	-2.3	-0.43	0.31	515	387	FALSE
22	418	-2.3	-0.42	0.21	514	387	FALSE
23	439	-2.26	-0.5	0.38	516	388	FALSE
24	458	-2.26	-0.52	0.41	516	388	FALSE
25	480	-2.28	-0.54	0.35	515	388	FALSE
26	501	-2.28	-0.6	0.34	515	389	FALSE

Gambar 3. Hasil plotting Roll dan Pitch dari .csv file (contoh kedua)

2. Pengujian terhadap Referensi MTw Awinda

Pada pengujian dengan referensi, referensi yang digunakan adalah: MTw Awinda dari XSens, Switzerland.

MTW Awinda diperoleh dari pembelian dana inventaris pada tahun pertama PTUPT ini (2019).

Adapun spesifikasi Xsens MTw Awinda:

Tabel 1. Spesifikasi teknis sensor dalam Xsens MTw Awinda [1]

	ACC	GYR	MAG	BAR
Sensor type	Digital	Digital	Digital	Digital
Full scale	$\pm$160 m/s^2	$\pm$2000 deg/s	$\pm$ 1.9 Gauss	300-1100 hPa
Non-linearity	0.5% of FS	0.1% of FS	0.1% of FS	0.05% of FS
Bias stability	0.1 mg	10 deg/hour	-	100 Pa/year
Noise	$200\mu g/\sqrt{Hz}$	0.01 deg/s/$\sqrt{Hz}$	0.2mGauss/$\sqrt{Hz}$	$0.85 Pa/\sqrt{Hz}$
Bandwidth	184 Hz	184 Hz	10-60 Hz (var.)	-
ADC sampling rate	1000 Hz (fix.)	1000 Hz (fix.)	20-120 Hz (var.)	20-60 Hz (var.)
SDI input rate	1000 Hz (fix.)	1000 Hz (fix.)	-	-
Output frame rate	20-120 Hz (var.)	20-120 Hz (var.)	20-120 Hz (var.)	20-60 Hz (var.)

*ACC=accelerometer; GYR=gyrometer; MAG=magnetometer; BAR=barometer

Berikut device yang digunakan dalam pengujian :

a. MTw motion tracker
b. Awinda dongle
c. Awinda station
d. MTw body strap, strap dibelitkan pada device uji.

Gambar 4 menunjukkan keempat bagian tersebut:

Gambar 4. Hardware Xsens MTw Awinda yang digunakan dalam pengujian

Sistem dan cara kerja MTw yang akan digunakan sebagai referensi adalah sebagai berikut:

A. MTw (gambar 4a)

MTw merupakan IMMU (Inertial-Magnetic Measurement Unit) yang berisi 3D gyroscope, 3D accelerometer dan 3D magnetometer dalam satu paket. Di dalamnya terdapat sensor fusion system. Bagian ini disebut *motion tracker*, setiap *motion tracker* akan mengirim datanya ke PC melalui *Awinda master* (Gambar 4c). *Awinda master* dapat berupa model station atau berupa USB dongle. Di PC diinstal aplikasi untuk perekaman data.

Kelemahan sistem transmisi dengan Wireless pada umumnya adalah:

1. Komunikasi dengan wireless tidak menjamin kecepatan transmisi yang tinggi, utamanya jika beberapa tracker dijalankan.
2. Adanya *packet lost* saat transmisi.
3. Akurasi kadang lemah sebab sinkronisasi yang meleset beberapa mili detik dapat berakibat kesalahan baca sudut dari pergerakan tubuh manusia yang sedang diukur.

Namun kekurangan-kekurangan diatas dapat diatasi oleh MTw Awinda dengan adanya: signal processing pipeline yang sudah dipatenkan, bernama SDI (Strap-Down Integration algorithm).

B. Awinda Master (gambar 4b dan 4c)

Awinda Master merupakan interface antara Awinda host berupa PC yang dilengkapi software Xsens, dengan satu atau lebih MTw. Awinda master menjamin sinkronisasi ke setiap MTw dengan periode 10us. Sebanyak 20 unit MTw dapat bersamaan beroperasi. Ada dua jenis Awinda Master yaitu model dongle (seperti pada gambar 4b) dan model station (seperti pada gambar 4c)

1. Awinda station (gambar 4c)

   Dalam station ini ada sebuah antenna dan 6 buah MTw docking slot. Docking ini dapat digunakan untuk alat charge bagi setiap MTw dan untuk *update firmware*. Dalam eksperimen yang berhubungan dengan pewaktuan, Awinda station dapat dihubungkan dengan piranti lain misalnya Arduino, RasPi, dan jenis komputer lain; oleh sebab itu Awinda station dilengkapi dengan 4 BNC connection untuk sinkronisasi pewaktuan dengan *third-parties* (device lain yang disambungkan kepada station). Disarankan jarak dengan MTw sekitar 50 meter (kondisi *line of* *sight*)

2. Awinda dongle (gambar 4b)

   Bentuk dongle seperti USB device pada umumnya. Dibandingkan dengan Awinda station, jangkauan dongle sekitar 10 m ke MTw. Dongle juga tidak dilengkapi konektor BNC untuk sinkronisasi pewaktuan dengan device lain saat eksperimen.

C. Awinda Host

   Penyebutan Awinda host lebih kepada API (application programming interface). Tugas Awinda host: sebagai penggabung (fusion) data-data dari sensor di MTw.

Tabel 2. Maksimum output frame rate vs jumlah MTw yang terhubung ke station

Jumlah MTw yang terhubung	Output frame rate maksimum (Hz)
1-5	120
6-9	100
10	80
11-20	60

3. Proses Pengujian

Pengujian sensor GY-951 untuk *upper-arm mouse* menggunakan referensi MTw Awinda. Gambar 5 menunjukkan blok diagram alur pengujian. Dalam gambar tersebut terdapat beberapa blok, penjelasan setiap blok-nya adalah sebagai berikut:

a. GY-951

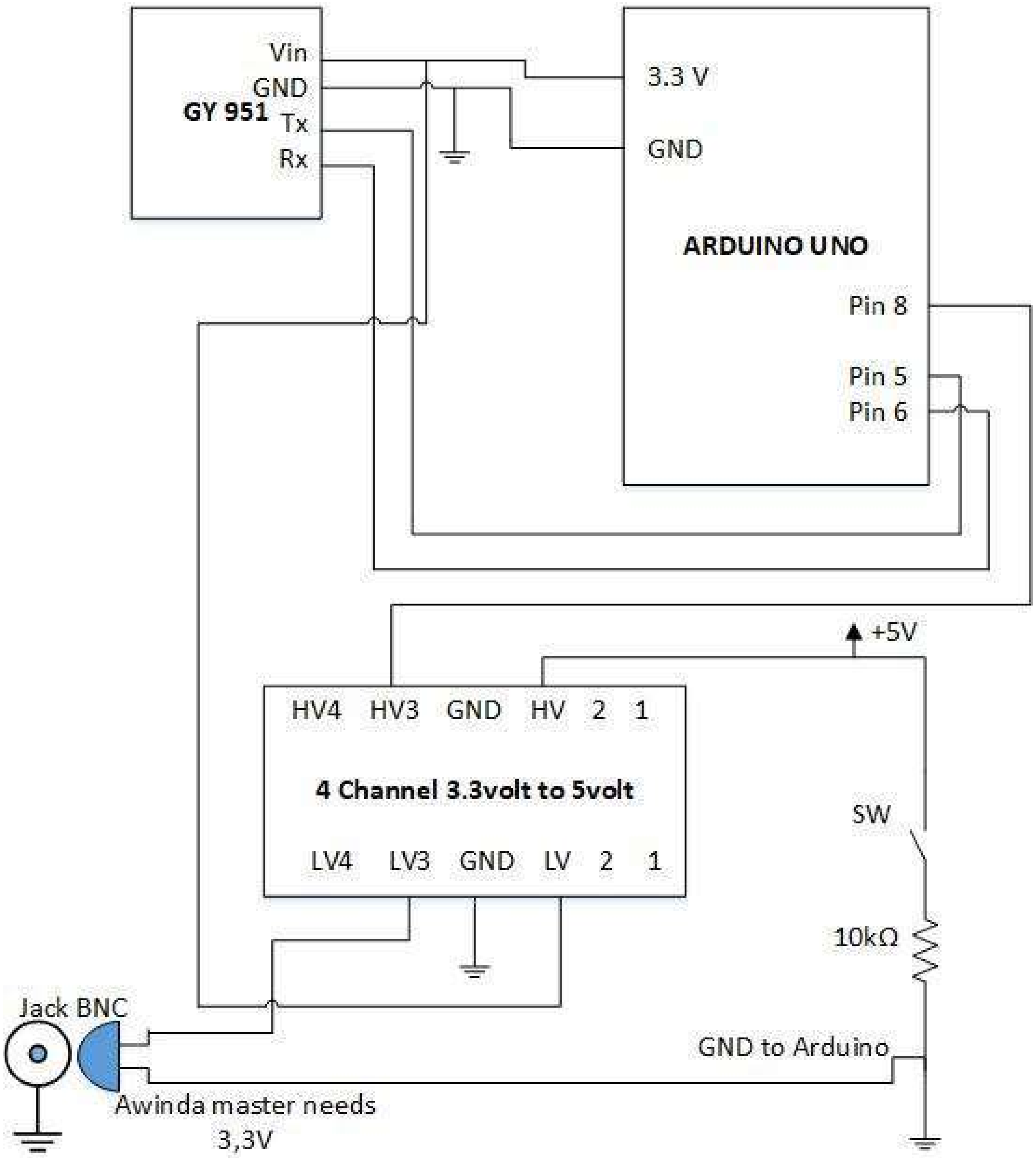
   Blok ini adalah sensor yang digunakan pada prototipe. Tegangan yang digunakan dimasukkan ke pin Vin sebesar 3.3 volt. Data sensor accelerometer dan gyrometer ditransmisikan secara serial ke Arduino melalui pin Tx dan Rx ke pin 5 dan 6 Arduino.

b. Arduino Uno

   Jenis Arduino yang digunakan adalah Uno. Arduino ini sebagai kontroler untuk:

   - Menerima data sensor dari GY-951
   - Menerima masukan dari Awinda master. Saat Awinda master mengirimkan sinyal "START" maka pin input nomor 8 digunakan program untuk menerima sinyal tersebut.

     Sinyal pada pin 8, akan digunakan untuk memberi tanda "Mulai merekam data".



Gambar 5. Blok diagram pengujian sistem

Jadi Arduino akan mulai mengambil data dari GY-951 jika pin 8 sudah menerima sinyal HIGH dari Awinda master. Gambar 6 adalah program pada Arduino dan hubungannya dengan Awinda master.

```
//Program untuk deteksi di Serial monitor (berhasil)
#include<SoftwareSerial.h>

#define buttonPin 8

SoftwareSerial myInertial(5,6); //(RX,TX) connect to (Tx,Rx) of GY-951

int lastButtonState = LOW;
unsigned long lastDebounceTime = 0;
unsigned long debounceDelay = 50;  //debounce time, bisa diganti
int buttonState;
int second_read = 0;
int ledState = LOW;

String inertial_value = "";

void setup() {
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(buttonPin, INPUT);

  // Open serial communication

  Serial.begin(57600);
  myInertial.begin(57600);
  myInertial.write("#ot");

  digitalWrite(LED_BUILTIN, LOW);
}

void loop() {

  //membaca input button sinkronisasi, button ditekan maka state = HIGH
  int reading = digitalRead(buttonPin);

 Serial.println("Belum");

 while (digitalRead(buttonPin) == HIGH){
   digitalWrite(LED_BUILTIN, HIGH);
   second_read = 1;
   inertial_value = myInertial.readStringUntil('\n');
   Serial.println(inertial_value);
}

  digitalWrite(LED_BUILTIN, LOW);
  Serial.println("SELESAI");

  //------------

  if (Serial.available()){ }
}
```

Gambar 6. Perangkat lunak Arduino yang berhubungan dengan Awinda master untuk sinkronisasi.

Gambar 7 menampilkan luaran serial monitor dari Arduino. Line 1, menandakan bahwa belum ada sinyal sinkronisasi dari Awinda master. Line 2-17 adalah contoh data sensor setelah Awinda master mulai pengukuran MTw Awinda. Sehingga di saat bersamaan Awinda master merekam data MTw Awinda.

```
1    Belum
2    #YPR=-179.63,-3.50,10.03
3    #YPR=-178.98,-3.47,10.02
4    #YPR=175.05,-12.72,-39.23
5    #YPR=175.75,-12.73,-39.20
6    #YPR=176.29,-12.70,-39.18
7    #YPR=175.92,-12.71,-39.21
8    #YPR=174.72,-12.72,-39.20
9    #YPR=175.44,-12.76,-39.16
10   #YPR=176.58,-12.79,-39.16
11   #YPR=176.71,-12.82,-39.13
12   #YPR=178.02,-12.81,-39.15
13   #YPR=178.51,-12.80,-39.14
14   #YPR=177.64,-12.82,-39.16
15   #YPR=177.74,-12.80,-39.22
16   #YPR=178.12,-12.82,-39.25
17   #YPR=177.68,-12.78,-39.29
18   SELESAI
19   Belum
20   SELESAI
21   Belum
22   SELESAI
```

Gambar 7. Tampilan serial monitor Arduino saat menerima data sensor dan sinkronisasinya dengan MTw master.

Gambar 8 menunjukkan cuplikan rekaman data MTw Awinda dengan menggunakan program host. Hasil rekaman berupa sensor Accelerometer tiga sumbu (x, y, dan z), sensor Gyro tiga sumbu (x, y, dan z), roll, pitch, dan yaw.

```
// Start Time: Unknown
// Update Rate: 100.0Hz
// Filter Profile: human (46.1)
// Firmware Version: 4.3.5
PacketCounter  SampleTimeFine  Acc_X  Acc_Y  Acc_Z  Gyr_X  Gyr_Y  Gyr_Z  Roll  Pitch  Yaw
19508  -1.634542  -7.908209  5.404188  0.016526  0.024784  -0.034013  -55.655489
19509  -1.296730  -8.004427  5.273373  -0.002749  -0.010536  -0.017563  -56.140414
19510  -1.646505  -7.889522  5.370466  0.019404  0.022949  -0.033271  -56.132594
19511  -1.260847  -7.996278  5.264704  -0.003633  -0.018541  -0.021154  -56.134863
19512  -1.601700  -7.876791  5.394658  0.014517  0.014406  -0.019898  -56.128562
19513  -1.263451  -8.021387  5.288437  -0.012184  -0.020848  0.002513  -56.133008
19514  -1.597847  -7.880149  5.340407  0.013143  0.020972  -0.011264  -56.127548
```

Gambar 8. Tampilan rekaman MTw serial monitor

c. Bagian ketiga dari blok adalah chip “4 channel 3.3V to 5V”
Chip ini berfungsi sebagai converter tegangan 3.3V menjadi 5V, dan sebaliknya. Chip ini perlu dipasang mengingat tegangan Arduino adalah 5V sedangkan tegangan Awinda station adalah 3.3V.

Untuk dapat menganalisis data secara *offline*, maka sebaiknya data dari serial monitor Arduino dapat disimpan kedalam file. Untuk dapat merekam transaksi data pada serial port, maka diperlukan software Coolterm. Coolterm dibuat oleh Robert Meier dan merupakan serial port terminal application. Coolterm digunakan untuk pertukaran data hardware yang terhubung ke serial port PC/laptop. Di dalam Coolterm ada fasilitas merekam data yang sedang melalui serial port ke dalam .txt file.

4. Proses Pengolahan Data Pengujian Sensor

Hasil pengujian memiliki dua file. Keduanya akan dibandingkan yaitu menghitung selisih/error. Sebab tujuan pengujian ini adalah mencari error sensor GY-951 terhadap referensi (MTw Awinda).

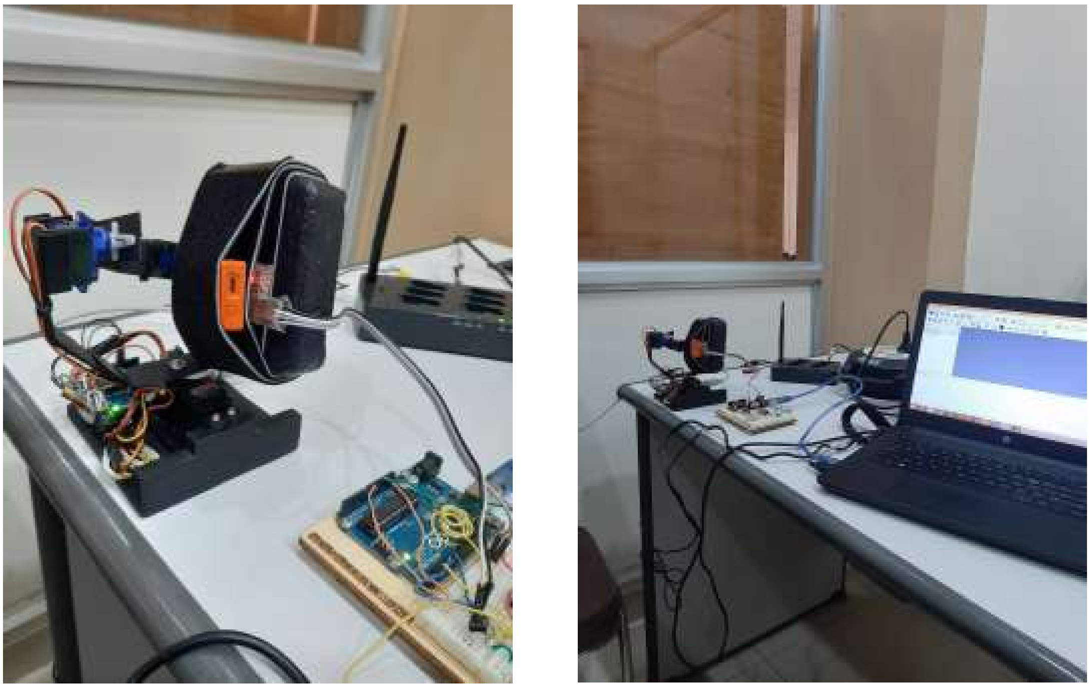
a. File pertama adalah .csv file dari software MTw master, seperti contoh tampilan di gambar 8.
b. File kedua adalah .txt file, hasil rekam bacaan Arduino terhadap sensor GY-951 dengan software Coolterm.

Kedua file diolah dengan .m file Matlab.

Metode pengujian:

1. MTw Awinda diikatkan pada suatu lengan diatas styroform. Disampingnya diikatkan sensor GY-951.
2. Lengan styroform diputar dengan servo motor. Gerakan yang digunakan yaitu roll, pitch, dan diam.

Gambar 9 merupakan foto peletakan sensor-sensor pada lengan styroform dan servo.



Gambar 9. Peletakan MTw Awinda dan sensor GY-951, servo yang memutar lengan percobaan.

Hasil pengolahan data menggunakan Matlab adalah sebagai berikut:

Laporan hasil error GY-951 dan MTAwinda (file: *main_olah_data02.m*)

- Ada 2 gerakan yaitu Pitch dan Roll
- Jumlah eksperimen Pitch: 3, Roll: 3, dan 1 posisi stationer
- Error yang dihitung di m file: RMSE (root mean square error) dan max error.
- Error dihitung selama 1200 sampel atau 12 detik, f sampling: 100Hz
- MTw Awinda (reference) menggunakan 100Hz sampling rate
- Error dihitung pada sampel ke 50 sampai 1250

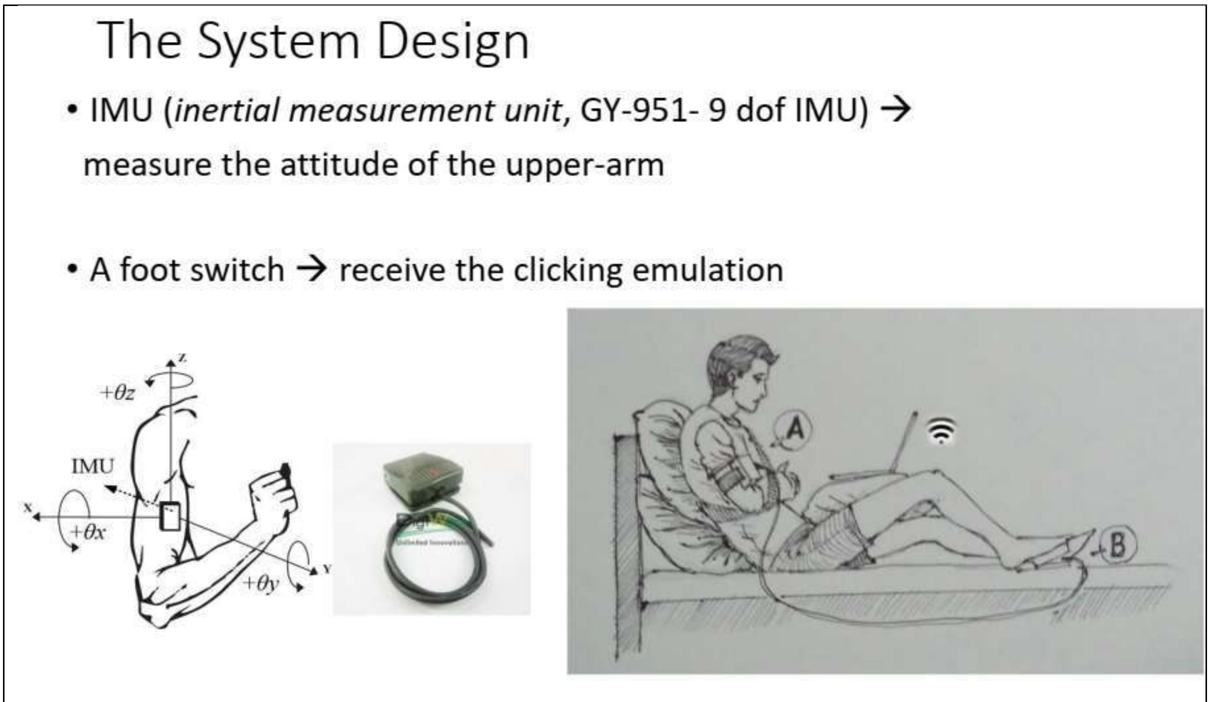
Tabel 3 menunjukkan hasil perhitungan error sensor terhadap MTw Awinda.

Tabel 3. Perhitungan selisih sudut sensor dengan MTw Awinda (reference)

	File	RMSE (deg)	Max Error (deg)	Rata-rata RMSE
1	Roll 1	73.81	7.52	
2	Roll 2	41.49	3.36	
3	Roll 3	73.76	5.38	63.02
4	a.Statis pada Pitch	1.81	0.17	
	b.Pada Roll	25.64	1.53	
5	Pitch 2	42.91	3.38	
6	Pitch 3	54.68	5.2	
7	Pitch 4	45.82	3.11	47.80

5. Pengujian Sistem pada Eksperimen Upper-arm Mouse

Pengujian sistem secara keseluruhan dilakukan terhadap 12 subjek. Berikut presentasi dan penjelasan terhadap pegujian sistem:

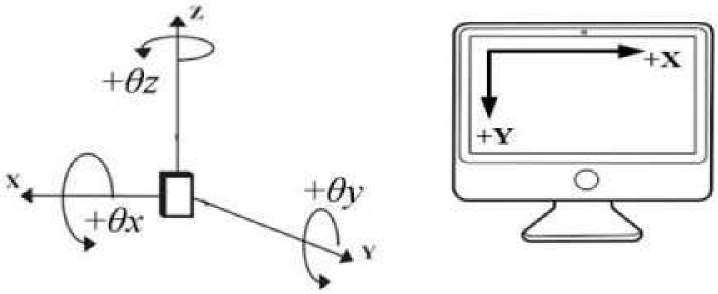


Desain sistem terdiri atas sensor IMU (yaitu GY-951) dan foot switch.
Sensor IMU akan digunakan untuk emulasi gerakan upper-arm menjadi gerakan kursor. Sedangkan foot switch dipakai untuk menggantikan klik kiri mouse. Gambar di atas menunjukkan posisi peletakan sensor dan ilustrasi seseorang yang dirawat di tempat tidur, dimana keadaan seperti itu membutuhkan alat bantu untuk mengendalikan komputer.

External and internal view of the proposed device

Tampilan di atas menunjukkan bentuk prototipe dari pandangan eksternal dan internal. Terdiri atas sensor GY-951, transmisi wifi (ESP32), dan charger system.

- Coordinate mapping from IMU to *monitor display*.

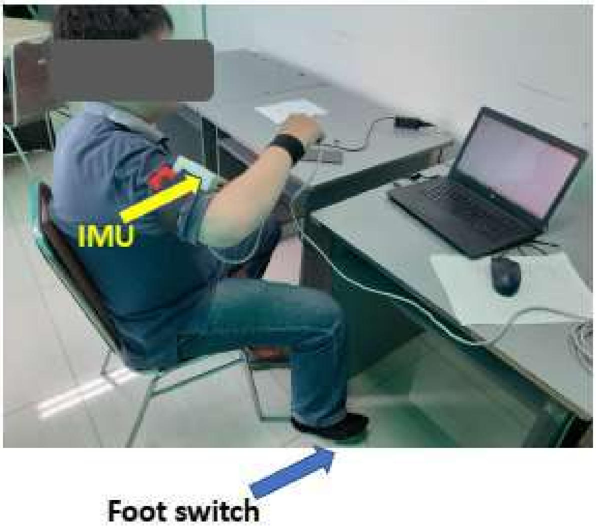


THE SENSOR-CURSOR MAPPING

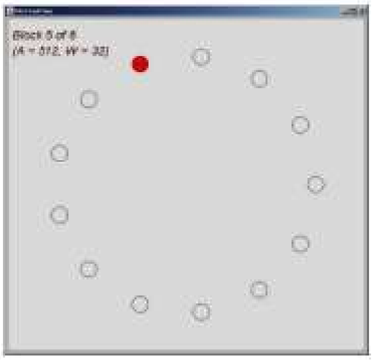
Gesture	DOF	Sensor (control)	Cursor (display)
Pitch-Roll	x		+
	y		-
	z		
	θ_y	+	
	θ_x	+	
	θ_z		

Coordinate mapping digunakan untuk memindahkan gerakan lengan yaitu Pitch dan Roll menjadi gerakan kursor mouse ke kiri-kanan, dan atas-bawah.

Experiment setting



Experiment setting menunjukkan posisi sensor IMU dan foot switch saat percobaan. Salah satu subjek dalam eksperimen adalah tuna daksa lengan bawah.



Experiment method

The FittsTaskTwo software (produced by Prof. I. Scott MacKenzie, York University, http://www.yorku.ca/mack/FittsTaskTwo.html).

- Participants: 12 subjects (average 22.4 ± 4.3 years old)
- Instrument: ISO 9241 part 411: Evaluation method for the design of physical input devices → Multidirectional tapping test.

→Four levels of difficulty: *very low, low, medium, high*

→*Two devices:* Mouse and proposed device

→Total trial per subject:

3 blocks x 4 levels of difficulty x 2 devices = 24 trials

Metode eksperimen:

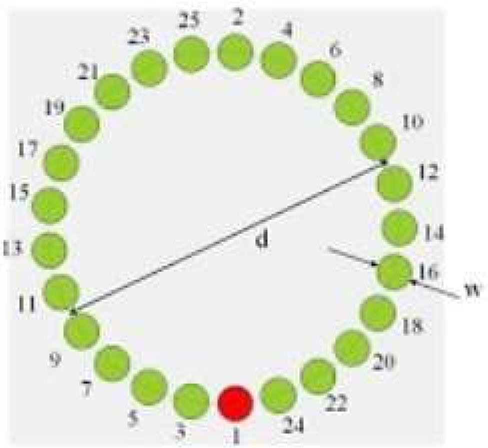
- Instrumen adalah multi direction tapping task, sesuai standar ISO 9241:411.
- Software menggunakan freeware dari York University.

- Partisipan 12 orang.
- Desain eksperimen: 3 blok eksperimen x 4 tingkat kesulitan x 2 device (mouse dan upper-arm mouse)

  Sehingga ada 24 trial per subjek.

ISO/TS 9241: part 411

- Multi-direction tapping task

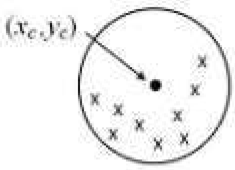


- Index of difficulty:

$$ID = \log_2 \frac{d + w}{w} \text{ (bit)}$$

- Four levels of difficulty:
  - *very low* (mode 1)
  - *low* (mode 2)
  - *medium* (mode 3)
  - *high* (mode 4)

Tingkat kesulitan pada penjelasan sebelumnya, diperoleh dari gabungan jarak antar target (d) dan diameter target (w).



Effective value, due to clicked-coordinate spreading of each target circle:

$$ID_e = \log_2 \frac{d + w_e}{w_e}; \; w_e = 4.133 s_x$$

A. The assessment of performance:

1. *Throughput* (*TP*)

$$TP = \frac{ID_e}{t_m}$$

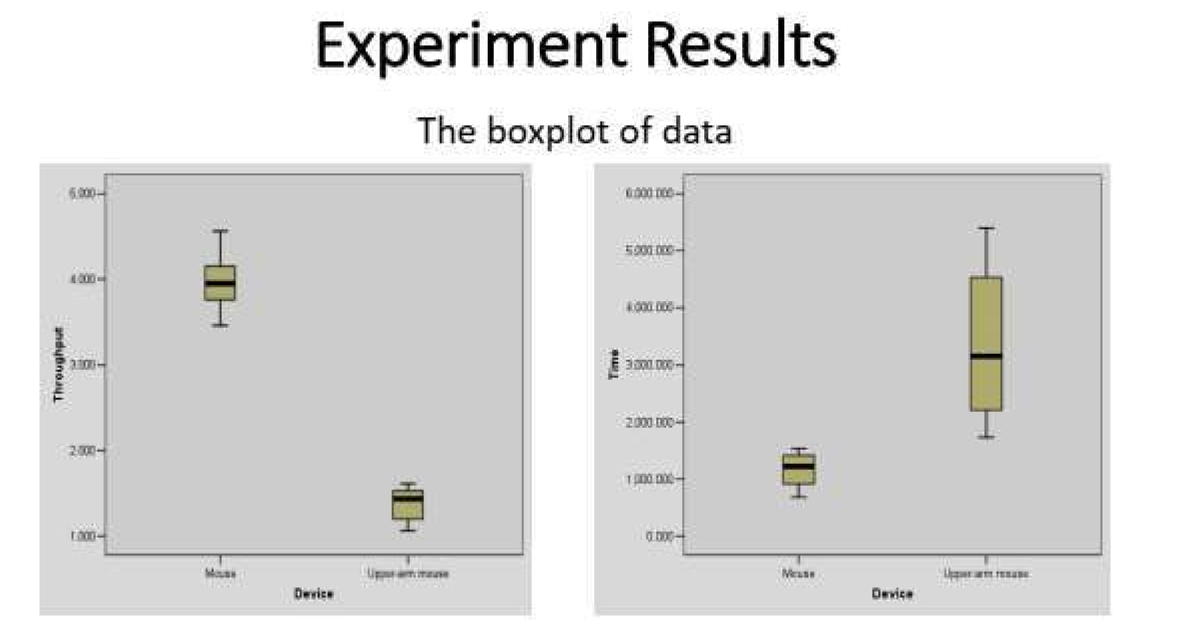
2. Movement time (t_m)

B. The assessment of comfort and fatigue:

Comfort and fatigue rating scale (7 + 5)

(questionnaires)

Ada dua variabel tergantung pada ISO9241:411 atau Fitts' law. *Throughput* adalah gabungan kecepatan dan tingkat kesulitan, yang ditemukan oleh Fitts (1956) dan disebut dalam Fitts' law. Sedangkan t_m adalah waktu yang ditempuh dari satu klik ke klik pada target berikutnya. Evaluasi berikutnya adalah menggunakan kuesioner untuk mengambil data kualitatif. Kuesioner digunakan untuk mengakses comfort test dan fatigue test.



Hasil eksperimen dalam boxplot untuk dua variabel terikat yaitu: Throughput (*TP*) dan movement time (t_m).

Experiment Results

- *Throughput (TP), movement time*

TABLE I. EXPERIMENT RESULTS IN DETAIL

B[1)]	M[2)]	Mouse		Upper-arm mouse (IMU+Foot switch)	
		t_m (s)	TP (bps)	t_m (s)	TP (bps)
1	1	0.836	3.465	1.896	1.494
	2	1.115	3.926	2.770	1.567
	3	1.353	3.976	4.222	1.192
	4	1.525	3.694	5.397	1.061
2	1	0.840	3.569	1.733	1.490
	2	1.001	4.102	2.533	1.612
	3	1.328	4.189	3.844	1.244
	4	1.475	4.117	4.986	1.120
3	1	0.677	4.563	1.751	1.480
	2	0.992	4.284	2.570	1.574
	3	1.355	3.823	3.535	1.394
	4	1.533	3.901	4.837	1.204
Mean		**1.169**	**3.97**	**3.34**	**1.37**

Notes: t_m = movement time; *TP* = throughput.
[1)]B = block
[2)]M = mode (difficulty level): 1=very low; 2=low; 3=high; 4=very high

- Mouse and (IMU+Footswitch) sensor were statistically different in either the *throughput* (*TP*) and *movement time* (t_m).
- The important finding is a significant difference in *throughput* and *movement time* between each level of difficulty in the (IMU+Footswitch) ($p < 0.05$)

(the difficulty level → the influential factor)

Hasil temuan menunjukkan bahwa *TP* dan t_m pada upper-arm mouse, pada setiap tingkat kesulitan memiliki perbedaan yang signifikan secara statistik.

Artinya setiap kenaikan level kesulitan, *TP* dan t_m memiliki perbedaan dengan level sebelumnya, dimana perbedaannya signifikan secara statistik. Hal ini menunjukkan bahwa penggunaan upper-arm mouse disarankan memperhatikan ukuran target dan jarak antar target, supaya error kecil dan *TP* bisa besar.

6. Penutup

Hasil uji coba produk dalam tahun kedua ini menunjukkan level TKT adalah 6. Prototipe telah menunjukkan bekerja fungsi-fungsi utamanya. Percobaan juga sudah dilakukan terhadap subjek yang melibatkan tuna daksa. Keterlibatan tuna daksa sejak tahun pertama memberikan dampak perbaikan prototipe di tahun kedua ini. Selanjutnya perlu dilakukan pengembangan prototipe ini ke level pasar dan mencari celah inovasi aplikasi supaya produk dapat menjadi produk inovasi.

7. Acknowledgement

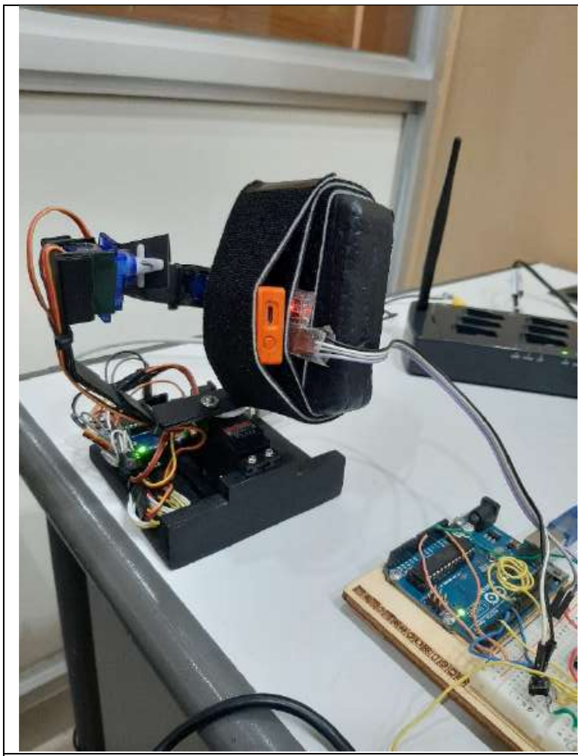
Peneliti dan tim mengucapkan terima kasih kepada semua subjek dalam uji coba produk ini. Peneliti dan tim berterima kasih atas support dari Kemenristek/BRIN yang telah memberikan support pendanaan dalam Penelitian Terapan Unggulan Perguruan Tinggi 2019-2020 ini.

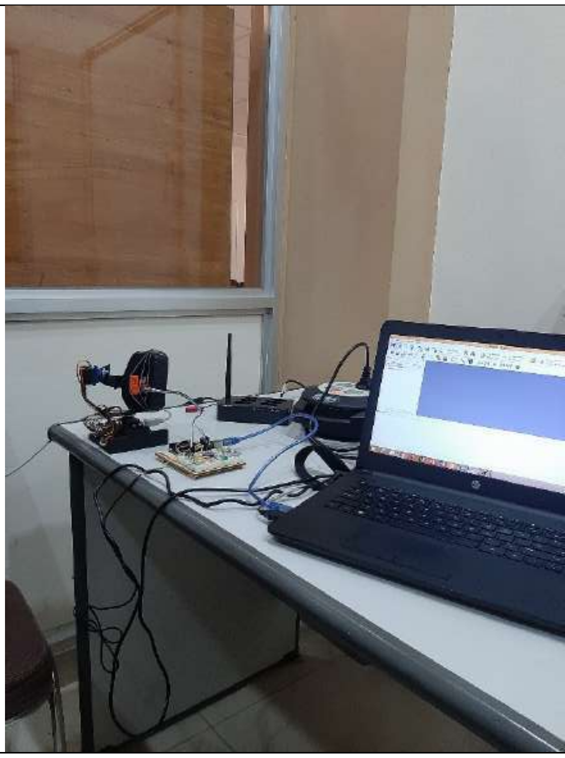
Dokumentasi (Foto) Pengujian Produk
Jenis produk:
“Teknologi Tepat Guna Mouse untuk Difabel Lengan Bawah”
PTUPT Tahun Kedua (terakhir) 2020
Ketua Peneliti: Dr. Eng. Romy Budhi, Universitas Ma Chung

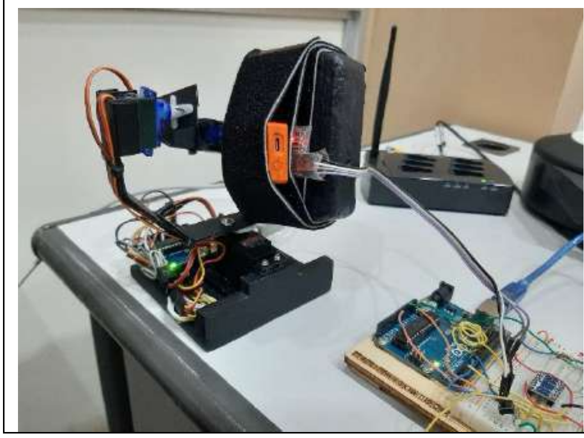
1. Pengujian sensor

Bahan:

Sensor GY-951 dan IMU MTw Awinda







2. Pengujian sistem

Bahan:

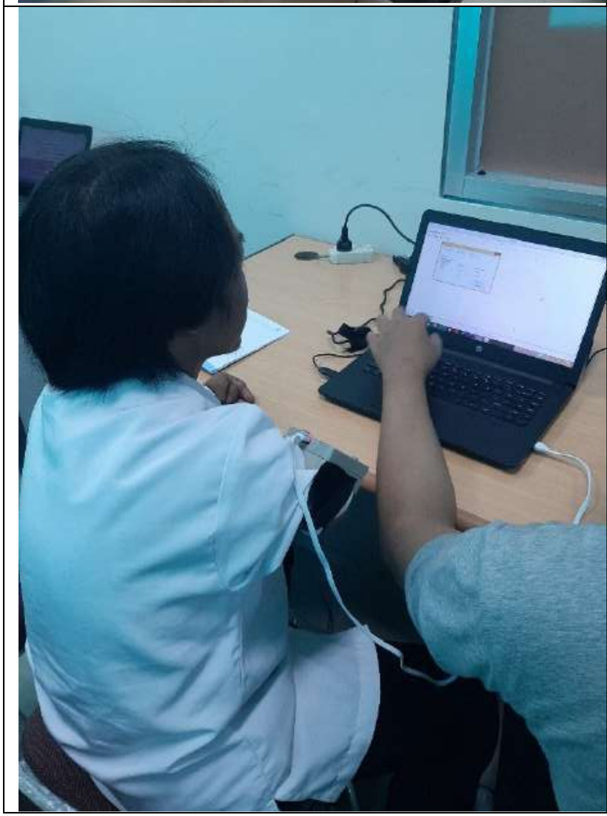
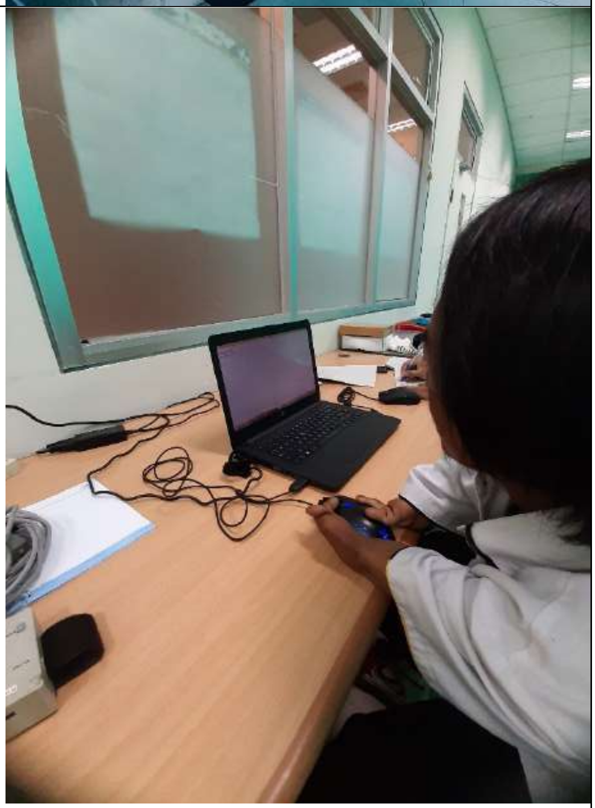
Prototipe hasil, software pengujian, bantuan subjek/partisipan









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Dokumen pendukung luaran Tambahan #1

Luaran dijanjikan: Keikutsertaan dalam Seminar Internasional

Target: sudah dilaksanakan
Dicapai: Accepted

Dokumen wajib diunggah:
1. Naskah artikel
2. Surat keterangan accepted dari editor

Dokumen sudah diunggah:
1. Naskah artikel
2. Surat keterangan accepted dari editor

Dokumen belum diunggah:
-

Peran penulis: first author
Nama Konferensi/Seminar: 2020 12th International Conference on Information Technology and Electrical Engineering (ICITEE)
Lembaga penyelenggara: Universitas Gajah Mada dan IEEE Indonesia Section
Tempat penyelenggara: Yogyakarta (virtual)
Tgl penyelenggaraan mulai: 6 Oktober 2020 | Tgl selesai: 8 Oktober 2020
Lembaga pengindeks: Scopus
URL website: http://icitee.ugm.ac.id/
Judul artikel: The Combination of Foot Switch and Low-Cost IMU for a Wearable Mouse in Human-computer Interaction

The Combination of Foot Switch and Low-Cost IMU for a Wearable Mouse in Human-computer Interaction

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***Abstract*—A wearable mouse using upper arm movement/ gesture is a promising pointing device that can be used by people with lower-arm disablement due to accident or prenatal disablement. The movement of the upper arm could be used to substitute the cursor movement. The use of an inertial measurement system is one way to capture the arm's movement in 3 dimensional spaces. The purposes of this study are the development of a new wearable mouse using the nine degree-of-freedom of inertial measurement unit and a foot switch for clicking action; and the evaluation of its performance on a specified level of difficulties. The device was evaluated by comparing the proposed device and a standard mouse. The performance indicators were throughput, movement time, comfort, and fatigue, based on Fitts' Law formula. The important finding is a significant ($p < 0.01$) difference in throughput between each level of difficulty in the proposed device by means of the target's distances and diameter/width in graphical user input design. The other finding showed no neck fatigue related differences between the proposed device and a mouse.**

Keywords—inertial sensor, low-cost IMU, human-computer interaction, wearable mouse

I. INTRODUCTION

The number of traffic accidents in Indonesia during 2004-2014 as reported in [1] showed a significant increase. The three levels of severity were described in the Abbreviated Injury Scale (AIS) created by Association for the Advancement of Automotive Medicine; i.e., fatalities, major injuries (AIS > 3+), and minor injuries (AIS < 3). The minor and major injuries, which were the first and second largest, could force the subject into bed rest during the rehabilitation period. Thus, they need an assistive technology to emulate the mouse for their daily work related to the computer. The second background of our study is based on the difficulties of people with special needs and disabilities in Indonesia who do not have a job. According the report in [2], 74.7% and 88.2% of people with special needs in Indonesia do not have jobs and do not continue on to junior high school, respectively. We presume the problem that causes persons with disabilities is not being able to use a mouse to operate a computer. Using our system, we hope new jobs related to computing work would open up for people with special needs.

For people with an injury in the forearm, the upper arm is the only part that could be used to substitute mouse movement. However, the upper limbs are more natural than the lower limbs in this case, since the mouse is moved by hand. By means of those, we used the lower limb as a stimulus for clicking action only and the movement of the upper arm to emulate mouse-cursor movement.

This paper would like to contribute a new wearable mouse using the upper arm and a foot switch, as well as an evaluation of the proposed system. The rest of this paper is organized as follows: Section II discusses the system of a wearable mouse, the evaluation of the system, and the related explanation of the experimental procedure. Section III discusses the result of the experiment. Finally, conclusions and future work are described.

II. WEARABLE MOUSE SYSTEM

The proposed system, as illustrated in Fig. 1, consists of an inertial measurement unit (IMU), foot switch, and a standard laptop with WIFI communication. The IMU typically determines attitude (roll and pitch) by combining the data from two sensors: accelerometer and gyroscope. The magnetometer is added when heading is necessary [3], [4]. The application of IMU as a three dimensional sensor is wide, such as in gait analysis [5], [6], and some effort using part of the IMU for people with special needs support tools, as in [7], [8]. The foot switch works based on the action of the pressure of the foot muscle and tendons. The '0' and '1' logic was introduced when the foot released and pressed the switch, respectively. The communication between the proposed device and the laptop wireless, using WIFI.

A. IMU GY-951 and Angle Determination Method

IMU GY-951 is a product of SMAKN®, and consists of an accelerometer using an ADXL345 chip, a gyroscope using an ITG3205 chip, and a magnetometer/digital compass using an HMC5883L chip; all sensors have 3 axes. The controller is a

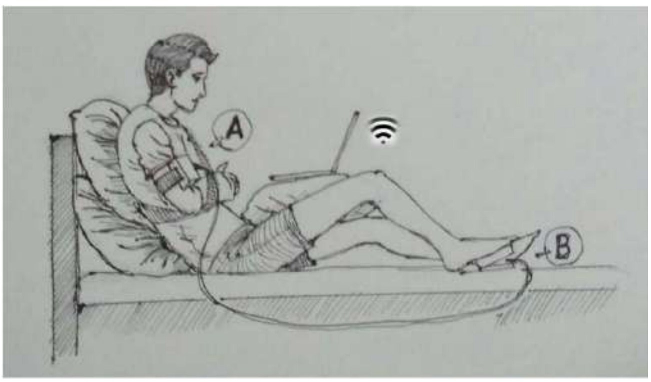
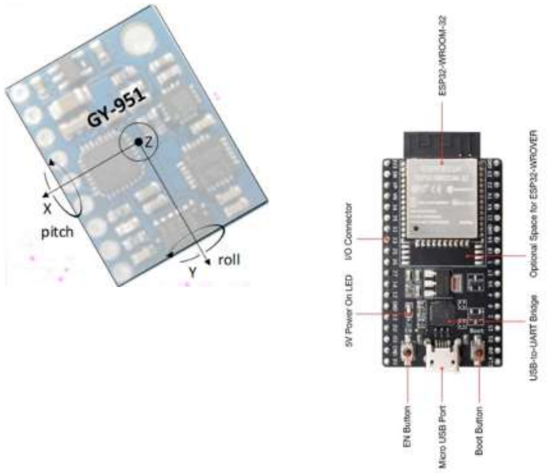


Fig. 1. Upper-arm wearable mouse system used by the bedridden: A) IMU sensor for cursor movement; B) Foot switch for clicking emulation.



(a) (b)

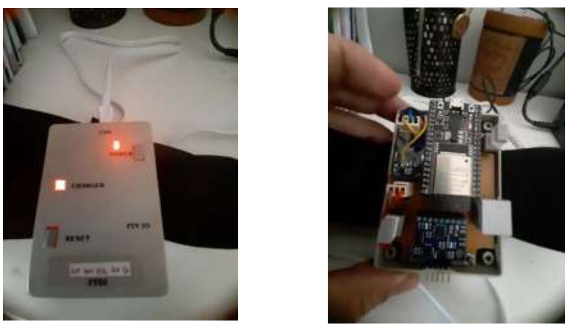
Fig. 2. a) Orientation of axes for GY-951; b) ESP32-DevKitC Board

Microchip 8-bit AVR microcontroller ATmega328. Figure 2a shows the orientation of the axes of sensitivity for IMU.

There are many methods to yield the roll, pitch, and yaw. In GY-951, the fusion of three sensors is done using a Direction Cosine Matrix (DCM) based on [9]. Many other fusion methods are also often used, such as a Kalman filter [4], [10], [11] and a complementary filter [12], [13].

B. ESP32-DevKitC Board

The ESP32-DevKitC board was used to handle the input from the foot switch and to control the communication between the foot switch, the IMU, and the laptop. Fig. 2b illustrates the ESP32-DevKitC board, which board consists of an ESP32-WROOM 32 chip, which is the main part of the board; an EN button; the boot button; the USB to UART bridge chip; a micro USB port; a 5V power on LED; and an I/O connector, which also supports PWM, ADC, DAC, I2S and serial communication protocol (i.e., I2C and SPI). Figure 3 shows the proposed device set.



(a) external view (b) internal view

Fig. 3. The set of the proposed device

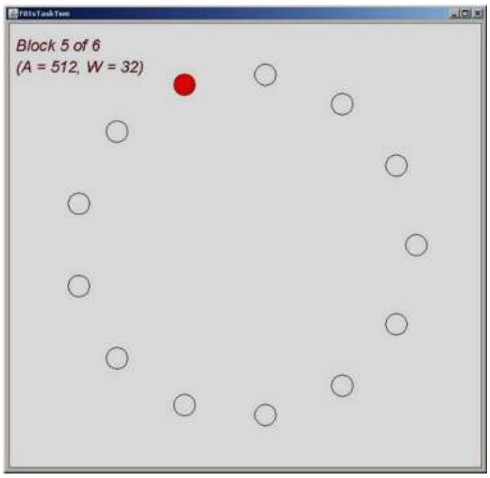


Fig. 4. The FittsTaskTwo software (produced by Prof. I. Scott MacKenzie, York University, http://www.yorku.ca/mack/FittsTaskTwo.html).

C. Experiment Design

Twelve participants, including one with lower arm disablement, participated in our study (average age 22.4 years old; s.d.: 4.3). Since within-subject design was used, we divided the participants into four groups and used a 4 x 4 Latin square design to arrange the four levels of difficulty for every group. The multidirectional task instrument based on Fitts' law theorem in ISO/TS 9241-411 (Ergonomics of human-system interaction standard) was used. The software was produced by Prof. I. Scott MacKenzie, York University, Canada; the original name of the software is FittsTaskTwo and the application name is GoFitts. Figure 4 illustrates the FittsTaskTwo software. The red circle is the target. "*A*" means the distance to the next target, while "*W*" is the target's diameter. The four levels of difficulty were based on the targets' distances and target diameter. Each subject tried 3 blocks in each difficulty level for the proposed device and a standard mouse, so the number of trials was 3 blocks x 4 levels of difficulty x 2 devices = 24 trials.

The IMU was attached to the biceps, as shown in Fig.1. The up-down movement of the cursor on the laptop monitor was brought about by the pitch movement of the upper arm, while the left-right movement of the cursor was brought about by the roll of the upper arm. The left-click action of the mouse was produced by foot press on the foot switch. The participant was free to determine whether to use their left or right foot on the foot switch.

The test measured the quantitative and qualitative aspects of human movement. The quantitative measurement was represented by throughput (*TP*) and movement time (t_m), while the qualitative measurement was represented by questionnaires concerning comfort, fatigue, and assessment of effort.

Fitts's law indicates that TP is the conclusion of speed and accuracy, and higher is better. The t_m indicates the average of time movement from initiation to target selection, a faster t_m indicating better performance. Higher comfort, lower fatigue, and lower effort indicate better performance. Figure 5 illustrates one of the experiment sessions.

Fig. 5. The experiment of the proposed device

III. Experiment Results

A. Quantitative Results

The spread of the data is represented using boxplots for the throughput (*TP*) and movement time (t_m), as illustrated in Fig. 6 and Fig. 7.

Table I describes the experiment results in detail, whereas Table II shows the diameter of the target and distance to the next target as the parameters for mode of difficulty.

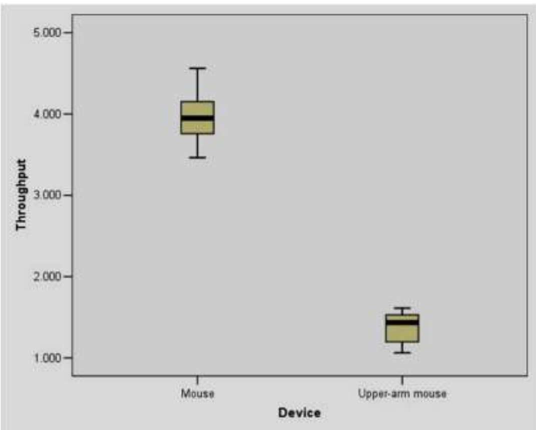


Fig. 6. The boxplot of throughput between a standard mouse and the proposed device

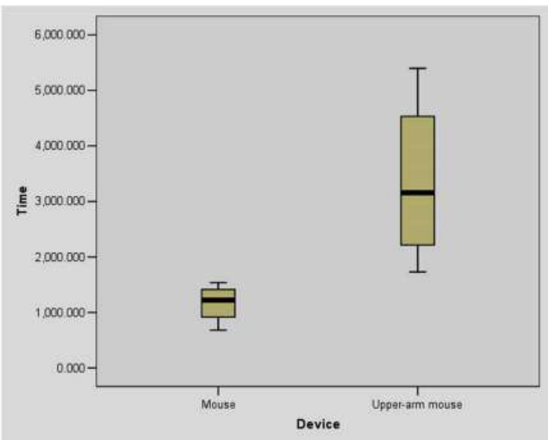


Fig. 7. The boxplot of movement time between a standard mouse and the proposed device

TABLE I. Experiment Results in Detail

B[1)]	M[2)]	Mouse		Upper-arm mouse (IMU+Foot switch)	
		t_m (s)	TP (bps)	t_m (s)	TP (bps)
1	1	0.836	3.465	1.896	1.494
	2	1.115	3.926	2.770	1.567
	3	1.353	3.976	4.222	1.192
	4	1.525	3.694	5.397	1.061
2	1	0.840	3.569	1.733	1.490
	2	1.001	4.102	2.533	1.612
	3	1.328	4.189	3.844	1.244
	4	1.475	4.117	4.986	1.120
3	1	0.677	4.563	1.751	1.480
	2	0.992	4.284	2.570	1.574
	3	1.355	3.823	3.535	1.394
	4	1.533	3.901	4.837	1.204
Mean		**1.169**	**3.97**	**3.34**	**1.37**

Notes: t_m = movement time; *TP* = throughput.

1)B = block

2)M = mode (difficulty level): 1=very low; 2=low; 3=high; 4=very high

TABLE II. The Design of Difficulty Level

Mode	Level of difficulty	Target diameter (W) (pixels)	Distance to the next target (A) (pixels)
1	Very low	80	200
2	Low	40	400
3	High	20	550
4	Very high	10	650

The mean comparison using paired-samples t-test (dependent t-test) results are as follows:

1. The proposed device has a statistically significant difference in *throughput* and *movement time* between each level of difficulty; i.e., between modes 3 and 4, between modes 2 and 3, and between modes 1 and 2 ($p < .05$).
2. The standard mouse only has statistical difference in *movement time* between each level of difficulty ($p < .05$).
3. The average *throughput* and *movement time* between the proposed device and mouse are statistically significant different ($p < .05$).

B. Qualitative Results

The seven questions of comfort level and five questions of fatigue were employed. The comfort level questions included:1) force required for actuation, 2) smoothness during operation, 3) effort required for operation, 4) accuracy, 5) operation speed, 6) general comfort, and 7) overall operation of input devices. The fatigue questions included: 1) finger fatigue, 2) wrist fatigue, 3) arm fatigue, 4) shoulder fatigue, and 5) neck fatigue. The Wilcoxon signed-rank test was used to compare differences between the proposed device and a standard mouse. The comfort level test indicates that a mouse is superior to the proposed device. Whereas in the fatigue test, neck fatigue (question number 5) did not show a significant difference between either device.

The Spearman's rank order correlation was used to determine the relationship between the proposed device and the mouse's effort. It shows a weak and positive correlation, which were statistically significant in the arm ($r_s = .582, p =$

.047). The Spearman's correlation in the shoulder and neck was reported as ($r_s = .227, p = .478$) and ($r_s = .537, p = .072$), respectively.

IV. Discussion

The important finding is the significant difference of *throughput* and *movement time* between each level of difficulty. The level of difficulty depends on the distance between two opposite targets and the diameter of the target, as shown in Table II. Therefore, the GUI design when using this proposed device should consider the size of the target. The smallest target in mode 4 resulted in poor *throughput* and *movement time*. The new proposal of using a foot switch as a clicking method resulted in TP = 1.37 bps (as in Table 1), which has a better result than a clicking method using the same arm as in our previous study (TP = 0.2 bps) [14]. We presume the use of one arm for cursor movement and clicking method at the same time would cause unstable cursor movement. The mouse performance is superior to the proposed device; in this study the mouse was only used as a baseline to check that our procedure was in line with other researchers.

The comfort level showed that a standard mouse has better comfort than the proposed device. We surmise that up to 90% of participants have more than 10 years of experience using a mouse. Although each participant learned to use the proposed device before the experiment, the mouse was still more comfortable. Neither device showed a difference in fatigue, which means that both devices have a great effect on neck fatigue. We presume that when a person uses the proposed device, the movement of the upper arm (pitch-roll) overburdens the neck muscles.

The correlation test shows that only the arm has a significant difference between the proposed device and a mouse; this means that both devices use significant effort in the arm, although the correlation not too high. For the effort in the shoulder and neck, neither device has a correlation. We presume the neck muscles did not use much effort during the use of the proposed device. However, for the mouse or other computer work, there is limited evidence of this causing tension neck syndrome, as stated in Table 1 in [15]. This result gives us the opportunity to consider neck fatigue in the next design of a wearable mouse.

V. Conclusion

In this paper we discussed a new wearable mouse using the IMU and foot switch for bedridden people or people with special needs. The combination of IMU and foot switch could increase the throughput and better movement time compared with our previous study. The qualitative result finds that neck effort for the proposed device causes fatigue. This is a suggestion for our next study. The effect of using either the left or right foot to press the foot switch is out of the scope in this study; however, it also a suggestion for the next study to investigate.

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[ICITEE 2020] Your paper #1570650037 ('The Combination of Foot Switch and Low-Cost IMU for a Wearable Mouse in Human-computer Interaction')

From: icitee2020-chairs@edas.info

To: romy_budhi@yahoo.com; 311710008@student.machung.ac.id; 311510028@student.machung.ac.id

Date: Tuesday, July 7, 2020, 03:30 AM GMT+7

Dear Dr. Romy Budhi Widodo:

Congratulations - your paper #1570650037 ('The Combination of Foot Switch and Low-Cost IMU for a Wearable Mouse in Human-computer Interaction') for 2020 12th International Conference on Information Technology and Electrical Engineering (ICITEE) has been **accepted**.

The reviews are below or can be found at https://edas.info/showPaper.php?m=1570650037.

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ICITEE 2020 review 1

Relevance and timeliness: Rate the importance and timeliness of the topic addressed in the paper within its area of research.

Acceptable (3)

Technical content and scientific rigour: Rate the technical content of the paper (e.g.: completeness of the analysis or simulation study, thoroughness of the treatise, accuracy of the models, etc.), its soundness and scientific rigour.

Valid work but limited contribution. (3)

Novelty and originality: Rate the novelty and originality of the ideas or results presented in the paper.

Some interesting ideas and results on a subject well investigated. (3)

Quality of presentation: Rate the paper organization, the clearness of text and figures, the completeness and accuracy of references.

Readable, but revision is needed in some parts. (3)

Recommendation: How do you rate your recommendation?

Possible Accept. (2)

Detailed comments: Please justify your recommendation and suggest improvements in technical content or presentation.

This paper describes a new wearable mouse using IMU and foot switch. While the work seems valid, there are several questions:

1. How to handle wide variance of the gait? It seems become the main problem for your cases.
2. What kind of filtering used in this work? Related above question, it is important to handle uncertainty of sensor reading.
3. Is there any other works which similar to this project? It is important to compare such system, at least comparison on the functionality

ICITEE 2020 review 2

Relevance and timeliness: Rate the importance and timeliness of the topic addressed in the paper within its area of research.

Excellent (5)

Technical content and scientific rigour: Rate the technical content of the paper (e.g.: completeness of the analysis or simulation study, thoroughness of the treatise, accuracy of the models, etc.), its soundness and scientific rigour.

Solid work of notable importance. (4)

Novelty and originality: Rate the novelty and originality of the ideas or results presented in the paper.

Significant original work and novel results. (4)

Quality of presentation: Rate the paper organization, the clearness of text and figures, the completeness and accuracy of references.

Well written. (4)

Recommendation: How do you rate your recommendation?

Accept. (3)

Detailed comments: Please justify your recommendation and suggest improvements in technical content or presentation.

Interesting topic and research, definitely have good contribution for HCI field.

The content can be improved by providing sample about how the test software works: what does the target look like, and how the difficulty progresses? Since the analysis also talks about " Therefore, the GUI design when using this proposed device should consider the size of the target." but we as readers did not get clear enough description about the test software.

Also in the discussion, maybe can point out which level difficulty is the most acceptable. Potentially this wearable mouse can be a new "assistive technology (AT)" to use for people with physical disability. In using AT sometimes we need adjustments in the software, so that touch targets can be bearable for the user group. This information therefore is valuable for future research of development of AT or web/software standards for a new AT.

ICITEE 2020 review 3

Relevance and timeliness: Rate the importance and timeliness of the topic addressed in the paper within its area of research.

Good (4)

Technical content and scientific rigour: Rate the technical content of the paper (e.g.: completeness of the analysis or simulation study, thoroughness of the treatise, accuracy of the models, etc.), its soundness and scientific rigour.

Excellent work and outstanding technical content. (5)

Novelty and originality: Rate the novelty and originality of the ideas or results presented in the paper.

Significant original work and novel results. (4)

Quality of presentation: Rate the paper organization, the clearness of text and figures, the completeness and accuracy of references.

Well written. (4)

Recommendation: How do you rate your recommendation?

Definite Accept. (4)

Detailed comments: Please justify your recommendation and suggest improvements in technical content or presentation.

The paper discusses the combination of foot switch and low-cost IMU for a wearable mouse. It proposes a hardware that combine the above two devices to replace usual mouse that can be used especially those who have some difficulties to move his/her arms.

The paper also shows the result of the experiment to compare the usual mouse with the proposed device. The statistical result shows the comparison between the two kind of mouse. The result is convincing and sound.

Dokumen pendukung luaran Tambahan #2

Luaran dijanjikan: Publikasi Ilmiah Jurnal Internasional

Target: accepted/published
Dicapai: Published

Dokumen wajib diunggah:
1.

Dokumen sudah diunggah:
1. Artikel yang terbit

Dokumen belum diunggah:
-

Nama jurnal: Journal of Engineering Science and Technology
Peran penulis: first author | EISSN: 1823-4690
Nama Lembaga Pengindek: Scopus, Web of Science
URL jurnal: http://jestec.taylors.edu.my/index.htm
Judul artikel: DESIGN AND EVALUATION OF UPPER-ARM MOUSE USING INERTIAL SENSOR FOR HUMAN-COMPUTER INTERACTION
Tahun: 2020 | Volume: 15 | Nomor: 6
Halaman awal: 3673 | akhir: 3690
URL artikel: http://jestec.taylors.edu.my/V15Issue6.htm
DOI: 000-000-000

Journal of Engineering Science and Technology
Vol. XX, No. Y (Year) PPP - QQQ

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]. The number of unemployed people with special needs is the background of this study. 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.

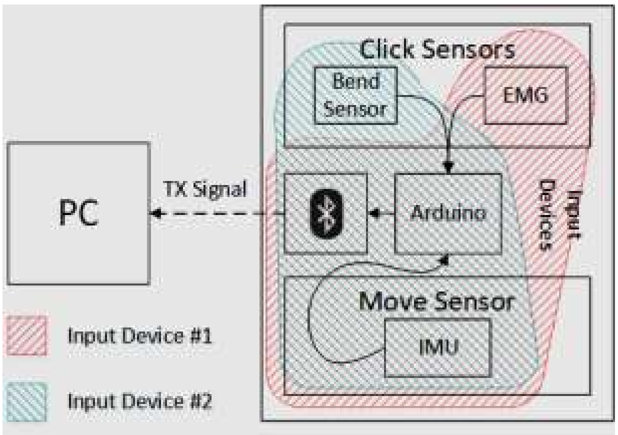


Fig. 2. Block diagram of input devices

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].

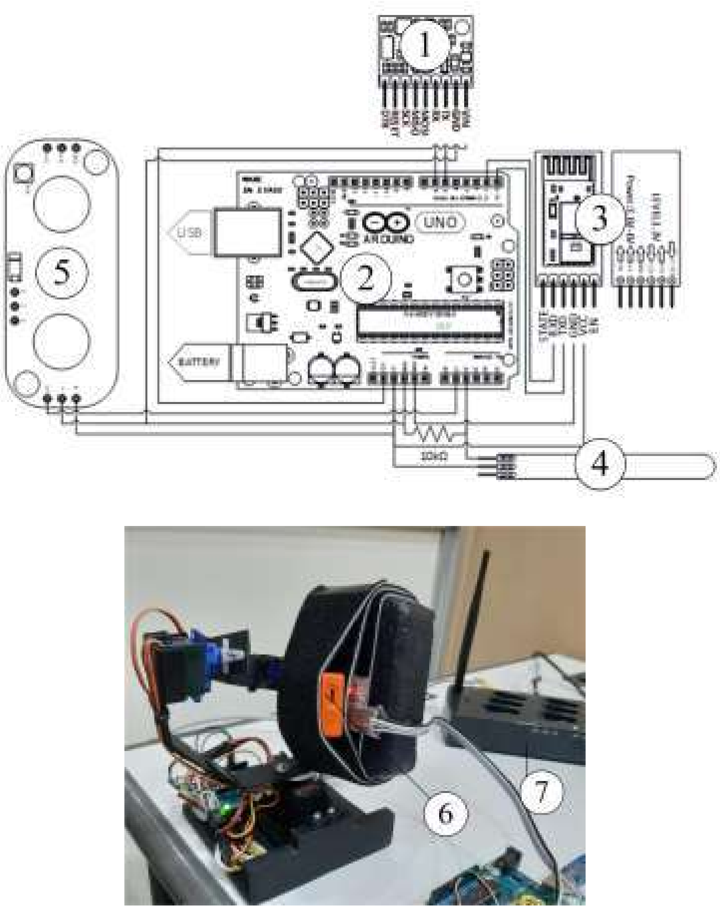


Fig. 3. Assembly of the input devices; each number aligns with the numbering of the device details noted in the text

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

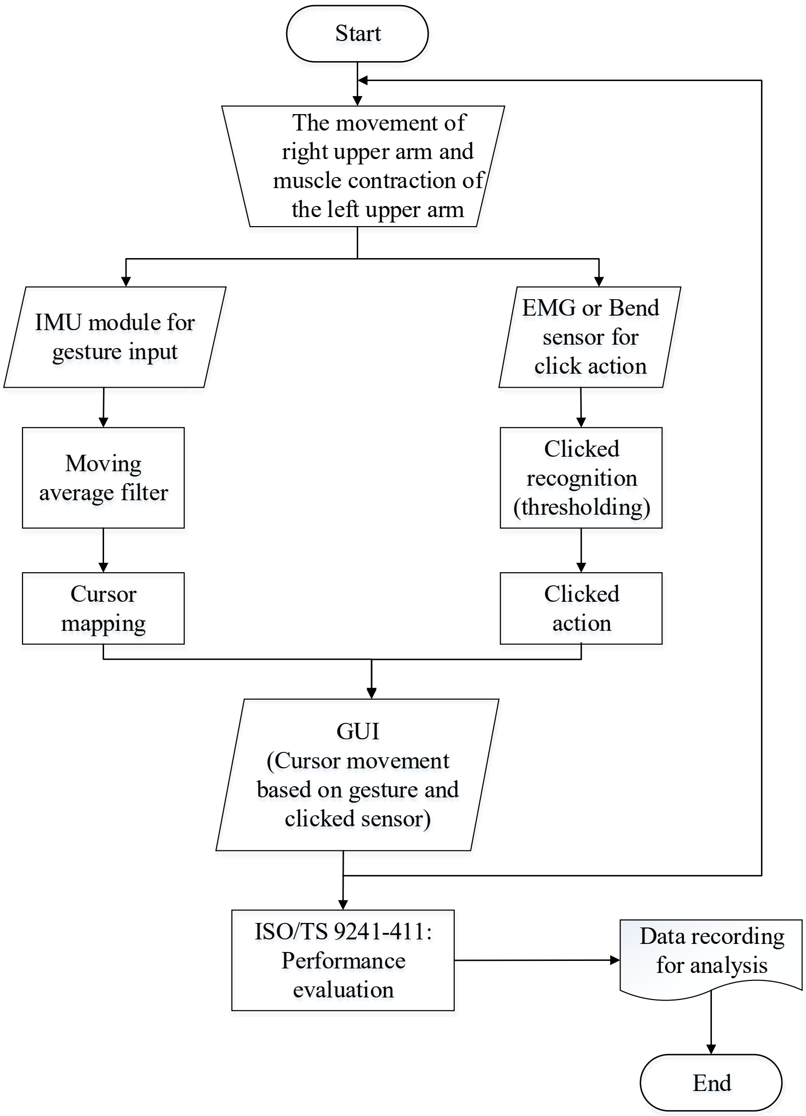


Fig. 4. The flowchart of software

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)

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

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).

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

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

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

$$W_e = 4.133\ S_x \tag{4}$$

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).

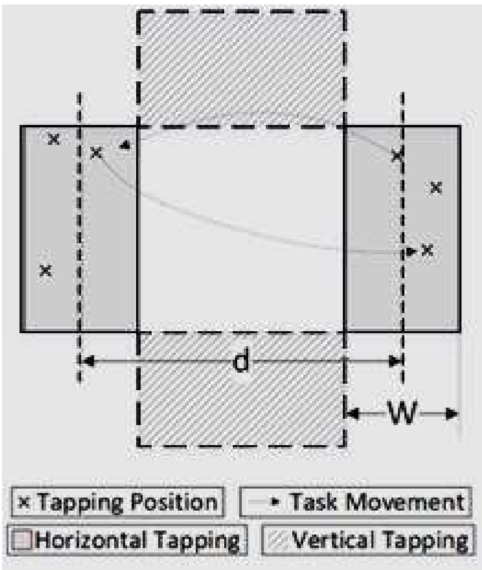


Fig. 5. The two-directional tapping test (horizontal and vertical tapping test), which includes variables *W* = width and *d* = distance

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.

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

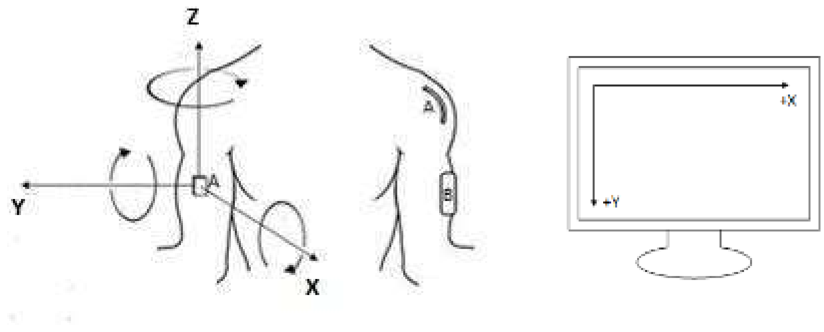
$$\bar{X}_{P_k} = \bar{X}_{P_{k-1}} + \frac{X_{P_k} - X_{P_{k-n}}}{n} \quad (6)$$

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.

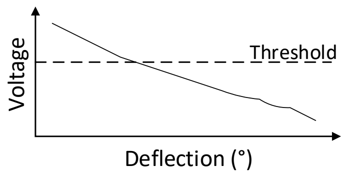


Fig. 7. Voltage and deflection relation graphic: The line of single threshold for the bend (flex) sensor

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.

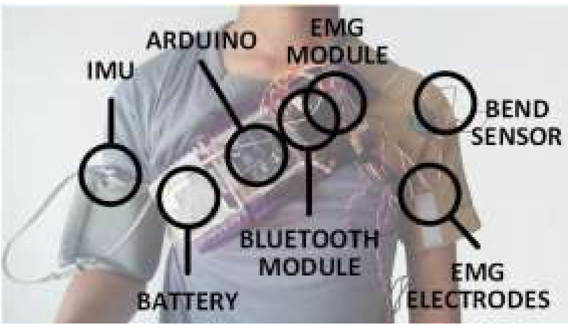


Fig. 8. Input devices mounted on the torso and lower arm, including labels for all device parts

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)

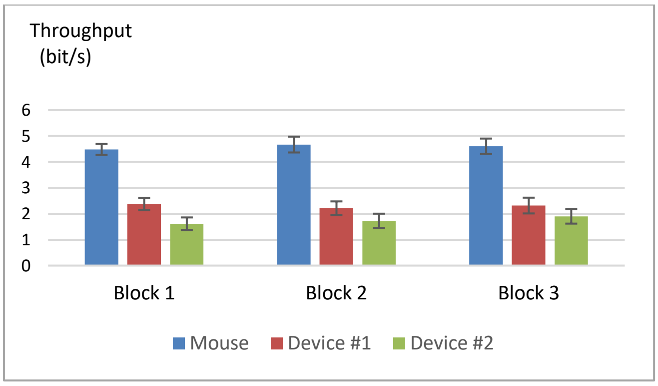
B[1)]	M[2)]	ID (bits)	Mouse				Device #1 (IMU+EMG)				Device #2 (IMU+Bend)			
			w_e (pixel)	ID_e (bits)	t_m (s)	TP (bps)	w_e (pixel)	ID_e (bits)	t_m (s)	TP (bps)	w_e (pixel)	ID_e (bits)	t_m (s)	TP (bps)
1	1	3.00	34.36	3.48	0.82	4.27	38.84	3.32	1.45	2.29	39.59	3.30	1.83	1.80
	2	3.22	42.95	3.66	0.85	4.32	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

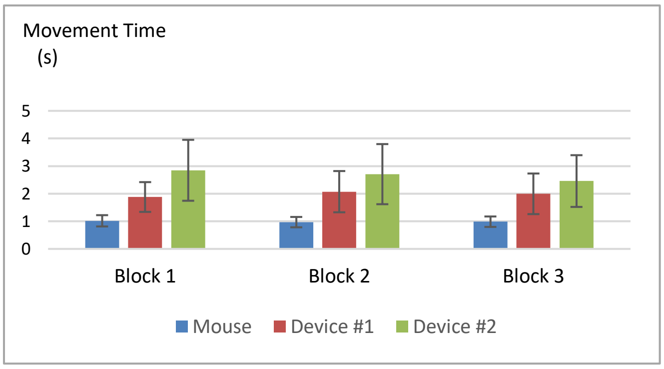
[2)]M = mode (difficulty level)

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.

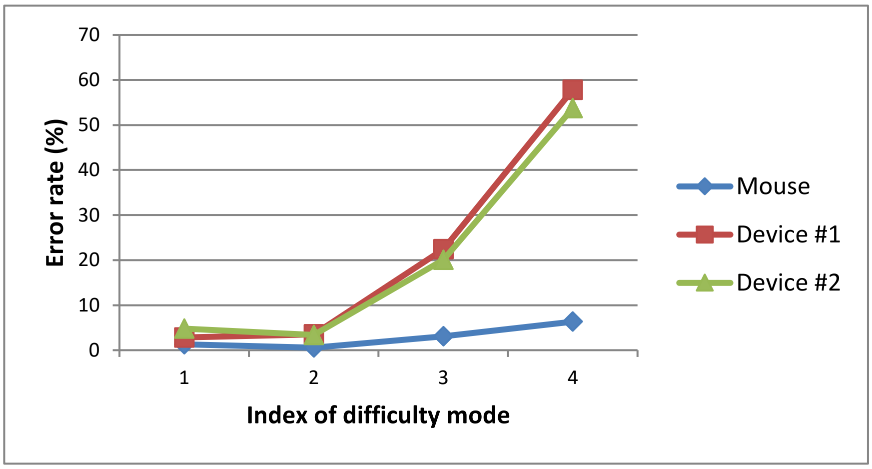


Fig. 10. Error rate per index of difficulty level

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.

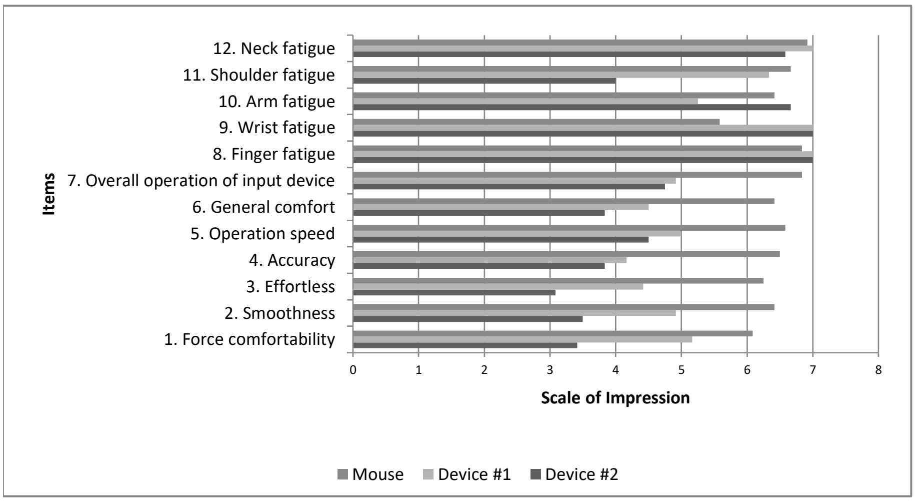


Fig. 11. Results of comfort and fatigue questionnaire

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

Acknowledgements

We acknowledged RISTEK BRIN Ministry of Research, Technology, and Higher Education Republic of Indonesia for supporting this research (Grant-in-aid Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT)).

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