Towards the Analysis of Movement Variability in the context of Human-Humanoid Imitation

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This dissertation is submitted for the degree of
Doctor of Philosophy

September 2018

I would like to dedicate this thesis to my loving parents ...

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 65,000 words including appendices, bibliography, footnotes, tables and equations and has fewer than 150 figures.

Miguel P. Xochicale
September 2018

Acknowledgements

And I would like to acknowledge ...

Abstract

This is where you write your abstract ...

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List of tables

Nomenclature

Roman Symbols

F	complex function

Greek Symbols

γ	a simply closed curve on a complex plane
$\imath$	unit imaginary number $\sqrt{-1}$
π	$\simeq 3.14\ldots$

Superscripts

j	superscript index

Subscripts

0	subscript index
crit	Critical state

Other Symbols

$\oint_\gamma$	integration around a curve γ

Acronyms / Abbreviations

ALU	Arithmetic Logic Unit
BEM	Boundary Element Method
CD	Contact Dynamics
CFD	Computational Fluid Dynamics

CIF Cauchy's Integral Formula

CK Carman - Kozeny

DEM Discrete Element Method

DKT Draft Kiss Tumble

DNS Direct Numerical Simulation

EFG Element-Free Galerkin

FEM Finite Element Method

FLOP Floating Point Operations

FPU Floating Point Unit

FVM Finite Volume Method

GPU Graphics Processing Unit

LBM Lattice Boltzmann Method

LES Large Eddy Simulation

MPM Material Point Method

MRT Multi-Relaxation Time

PCI Peripheral Component Interconnect

PFEM Particle Finite Element Method

PIC Particle-in-cell

PPC Particles per cell

RVE Representative Elemental Volume

SH Savage Hutter

SM Streaming Multiprocessors

USF Update Stress First

USL Update Stress Last

Chapter 1

Introduction

1.1 Opening hook

1.2 Context

1.3 Gap in the literature

1.4 Research Questions

1.5 Argument

1.6 Outline of logic

1.7 What is loren ipsum? Title with math σ

Lorem Ipsum is simply dummy text of the printing and typesetting industry (see Section 1.9). Lorem Ipsum [3] has been the industry's standard dummy text ever since the 1500s, when an unknown printer took a galley of type and scrambled it to make a type specimen book. It has survived not only five centuries, but also the leap into electronic typesetting, remaining essentially unchanged. It was popularised in the 1960s with the release of Letraset sheets containing Lorem Ipsum passages, and more recently with desktop publishing software like Aldus PageMaker including versions of Lorem Ipsum [1, 4, 5].

The most famous equation in the world: $E^2 = (m_0c^2)^2 + (pc)^2$, which is known as the **energy-mass-momentum** relation as an in-line equation.

A *LaTeX class file* is a file, which holds style information for a particular LaTeX.

$$CIF: \quad F_0^j(a) = \frac{1}{2\pi\imath} \oint_\gamma \frac{F_0^j(z)}{z-a} dz \tag{1.1}$$

1.8 Why do we use loren ipsum?

It is a long established fact that a reader will be distracted by the readable content of a page when looking at its layout. The point of using Lorem Ipsum is that it has a more-or-less normal distribution of letters, as opposed to using 'Content here, content here', making it look like readable English. Many desktop publishing packages and web page editors now use Lorem Ipsum as their default model text, and a search for 'lorem ipsum' will uncover many web sites still in their infancy. Various versions have evolved over the years, sometimes by accident, sometimes on purpose (injected humour and the like).

1.9 Where does it come from?

Contrary to popular belief, Lorem Ipsum is not simply random text. It has roots in a piece of classical Latin literature from 45 BC, making it over 2000 years old. Richard McClintock, a Latin professor at Hampden-Sydney College in Virginia, looked up one of the more obscure Latin words, consectetur, from a Lorem Ipsum passage, and going through the cites of the word in classical literature, discovered the undoubtable source. Lorem Ipsum comes from sections 1.10.32 and 1.10.33 of "de Finibus Bonorum et Malorum" (The Extremes of Good and Evil) by Cicero, written in 45 BC. This book is a treatise on the theory of ethics, very popular during the Renaissance. The first line of Lorem Ipsum, "Lorem ipsum dolor sit amet..", comes from a line in section 1.10.32.

The standard chunk of Lorem Ipsum used since the 1500s is reproduced below for those interested. Sections 1.10.32 and 1.10.33 from "de Finibus Bonorum et Malorum" by Cicero are also reproduced in their exact original form, accompanied by English versions from the 1914 translation by H. Rackham

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Section 1.10.32 of “de Finibus Bonorum et Malorum", written by Cicero in 45 BC: “Sed ut perspiciatis unde omnis iste natus error sit voluptatem accusantium doloremque laudantium, totam rem aperiam, eaque ipsa quae ab illo inventore veritatis et quasi architecto beatae vitae dicta sunt explicabo. Nemo enim ipsam voluptatem quia voluptas sit aspernatur aut odit aut fugit, sed quia consequuntur magni dolores eos qui ratione voluptatem sequi nesciunt. Neque porro quisquam est, qui dolorem ipsum quia dolor sit amet, consectetur, adipisci velit, sed quia non numquam eius modi tempora incidunt ut labore et dolore magnam aliquam quaerat voluptatem. Ut enim ad minima veniam, quis nostrum exercitationem ullam corporis suscipit laboriosam, nisi ut aliquid ex ea commodi consequatur? Quis autem vel eum iure reprehenderit qui in ea voluptate velit esse quam nihil molestiae consequatur, vel illum qui dolorem eum fugiat quo voluptas nulla pariatur?"

1914 translation by H. Rackham: “But I must explain to you how all this mistaken idea of denouncing pleasure and praising pain was born and I will give you a complete account of the system, and expound the actual teachings of the great explorer of the truth, the master-builder of human happiness. No one rejects, dislikes, or avoids pleasure itself, because it is pleasure, but because those who do not know how to pursue pleasure rationally encounter consequences that are extremely painful. Nor again is there anyone who loves or pursues or desires to obtain pain of itself, because it is pain, but because occasionally circumstances occur in which toil and pain can procure him some great pleasure. To take a trivial example, which of us ever undertakes laborious physical exercise, except to obtain some advantage from it? But who has any right to find fault with a man who chooses to enjoy a pleasure that has no annoying consequences, or one who avoids a pain that produces no resultant pleasure?"

Section 1.10.33 of “de Finibus Bonorum et Malorum", written by Cicero in 45 BC: “At vero eos et accusamus et iusto odio dignissimos ducimus qui blanditiis praesentium voluptatum deleniti atque corrupti quos dolores et quas molestias excepturi sint occaecati cupiditate non provident, similique sunt in culpa qui officia deserunt mollitia animi, id est laborum et dolorum fuga. Et harum quidem rerum facilis est et expedita distinctio. Nam libero tempore, cum soluta nobis est eligendi optio cumque nihil impedit quo minus id quod maxime placeat facere possimus, omnis voluptas assumenda est, omnis dolor repellendus. Temporibus autem quibusdam et aut officiis debitis aut rerum necessitatibus saepe eveniet ut et voluptates repudiandae sint et molestiae non recusandae. Itaque earum rerum hic tenetur a sapiente delectus, ut aut reiciendis voluptatibus maiores alias consequatur aut perferendis doloribus asperiores repellat."

1914 translation by H. Rackham: “On the other hand, we denounce with righteous indignation and dislike men who are so beguiled and demoralized by the charms of pleasure

of the moment, so blinded by desire, that they cannot foresee the pain and trouble that are bound to ensue; and equal blame belongs to those who fail in their duty through weakness of will, which is the same as saying through shrinking from toil and pain. These cases are perfectly simple and easy to distinguish. In a free hour, when our power of choice is untrammelled and when nothing prevents our being able to do what we like best, every pleasure is to be welcomed and every pain avoided. But in certain circumstances and owing to the claims of duty or the obligations of business it will frequently occur that pleasures have to be repudiated and annoyances accepted. The wise man therefore always holds in these matters to this principle of selection: he rejects pleasures to secure other greater pleasures, or else he endures pains to avoid worse pains."

Chapter 2

Literature Review

2.1 Source of Variability in Human Movement

2.2 Sensors

2.3 Variability within and between persons

2.4 Variability for simple and complex activities

2.5 Techniques to measure human movement variability

2.6 Reasonably long section title

I'm going to randomly include a picture Figure 2.1.

If you have trouble viewing this document contact Krishna at: kks32@cam.ac.uk or raise an issue at https://github.com/kks32/phd-thesis-template/

Enumeration

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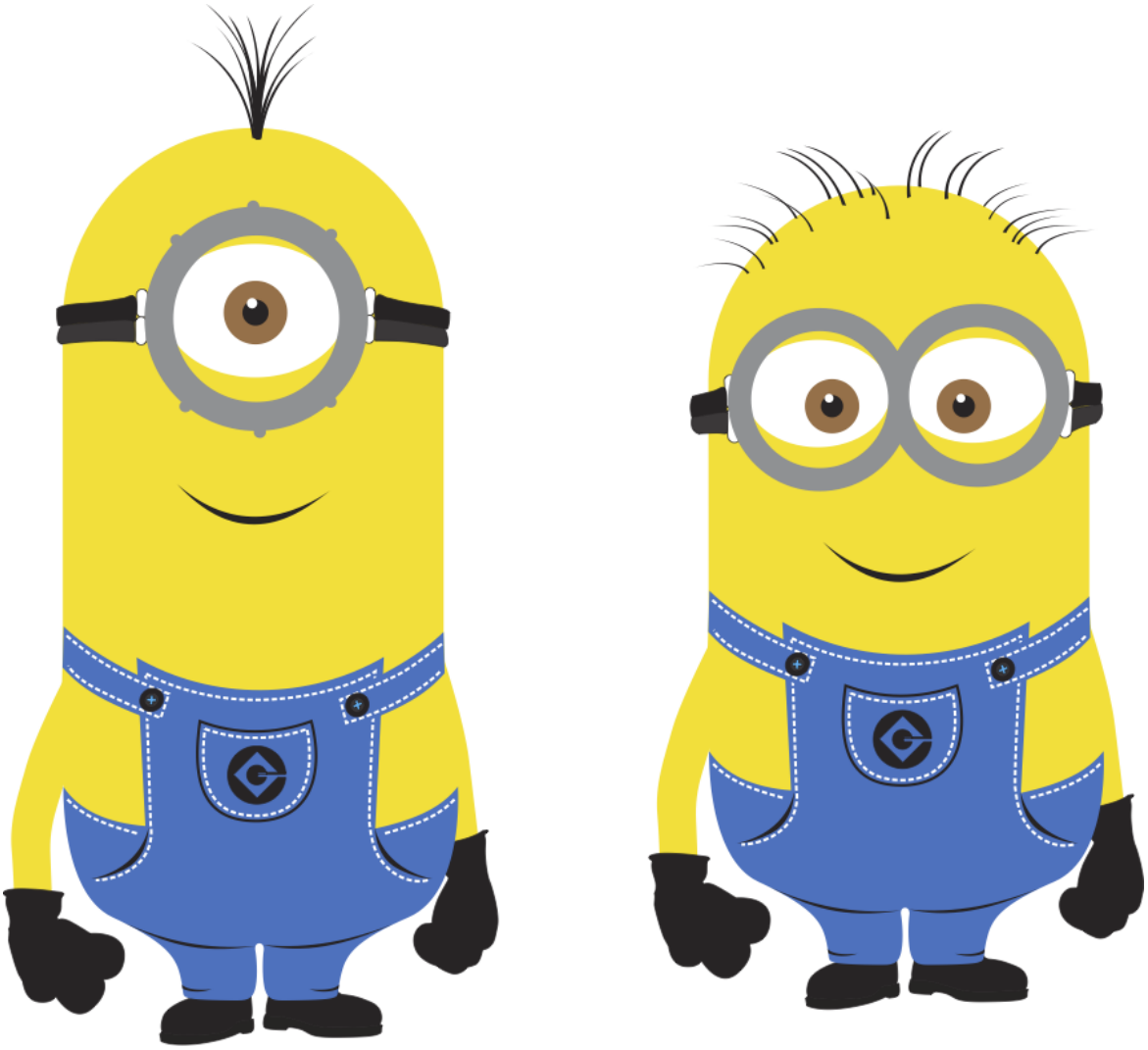

Fig. 2.1 This is just a long figure caption for the minion in Despicable Me from Pixar

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2. The second topic is duller
    (a) The first subtopic is silly
    (b) The second subtopic is stupid
3. The third topic is the dullest

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Itemize

- The first topic is dull
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Description

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The second subtopic is stupid

The third topic is the dullest

2.7 Hidden section

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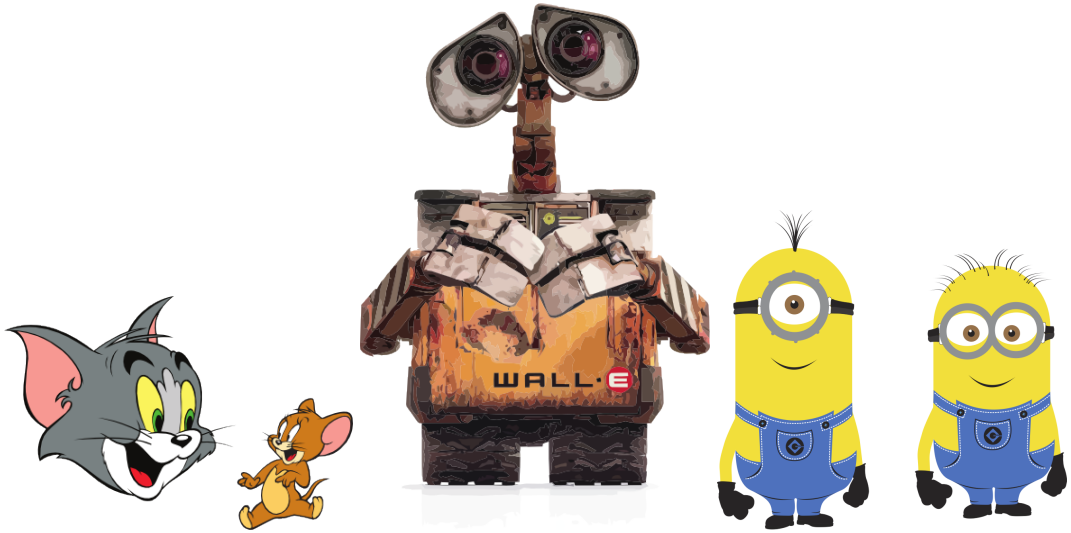
[1] My footnote goes blah blah blah! ...



(a) Tom and Jerry (b) Wall-E (c) Minions

Fig. 2.2 Best Animations

Subplots

I can cite Wall-E (see Fig. 2.2b) and Minions in despicable me (Fig. 2.2c) or I can cite the whole figure as Fig. 2.2

Chapter 3

Methodology

3.1 Time-domain

3.2 Frequency-domain

3.3 Nonlinear dynamics domain

3.4 First section of the third chapter

And now I begin my third chapter here . . .

And now to cite some more people Read [6], Ancey et al. [2]

3.4.1 First subsection in the first section

. . . and some more

3.4.2 Second subsection in the first section

. . . and some more . . .

First subsub section in the second subsection

. . . and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it . . .

3.4.3 Third subsection in the first section

. . . and some more . . .

First subsub section in the third subsection

. . . and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it and some more and some more and some more and some more and some more and some more and some more . . .

Second subsub section in the third subsection

. . . and some more in the first subsub section otherwise it all looks the same doesn't it? well we can add some text to it . . .

3.5 Second section of the third chapter

and here I write more . . .

3.6 The layout of formal tables

This section has been modified from "Publication quality tables in LaTeX*" by Simon Fear.

The layout of a table has been established over centuries of experience and should only be altered in extraordinary circumstances.

When formatting a table, remember two simple guidelines at all times:

1. Never, ever use vertical rules (lines).

2. Never use double rules.

These guidelines may seem extreme but I have never found a good argument in favour of breaking them. For example, if you feel that the information in the left half of a table is so different from that on the right that it needs to be separated by a vertical line, then you should use two tables instead. Not everyone follows the second guideline:

There are three further guidelines worth mentioning here as they are generally not known outside the circle of professional typesetters and subeditors:

3. Put the units in the column heading (not in the body of the table).

Table 3.1 A badly formatted table

	Species I		Species II	
Dental measurement	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Table 3.2 A nice looking table

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

4. Always precede a decimal point by a digit; thus 0.1 *not* just .1.

5. Do not use 'ditto' signs or any other such convention to repeat a previous value. In many circumstances a blank will serve just as well. If it won't, then repeat the value.

A frequently seen mistake is to use '\begin{center}' ... '\end{center}' inside a figure or table environment. This center environment can cause additional vertical space. If you want to avoid that just use '\centering'

Table 3.3 Even better looking table using booktabs

Dental measurement	Species I		Species II	
	mean	SD	mean	SD
I1MD	6.23	0.91	5.2	0.7
I1LL	7.48	0.56	8.7	0.71
I2MD	3.99	0.63	4.22	0.54
I2LL	6.81	0.02	6.66	0.01
CMD	13.47	0.09	10.55	0.05
CBL	11.88	0.05	13.11	0.04

Chapter 4

Experiments

4.1 Dancing Salsa

4.2 Simple movements

4.3 Human-Humanoid Imitation

4.4 Group Activity in Human-Humanoid Imitation

4.5 Reasonably long section title

Enumeration

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4.6 Hidden section

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Chapter 5

Automatic Classification

5.1 Convolutional Neural Networks

5.2 Convolutional Neural Networks Using time-series

5.3 Reasonably long section title

Enumeration

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Chapter 6

Conclusion

6.1 Reasonably long section title

Enumeration

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References

[1] Abramovich, Y. A., Aliprantis, C. D., and Burkinshaw, O. (1995). Another characterization of the invariant subspace problem. *Operator Theory in Function Spaces and Banach Lattices.* The A.C. Zaanen Anniversary Volume*, Operator Theory: Advances and Applications*, 75:15–31. Birkhäuser Verlag.

[2] Ancey, C., Coussot, P., and Evesque, P. (1996). Examination of the possibility of a fluid-mechanics treatment of dense granular flows. *Mechanics of Cohesive-frictional Materials*, 1(4):385–403.

[3] Aupetit, B. (1991). *A Primer on Spectral Theory*. Springer-Verlag, New York.

[4] Conway, J. B. (1990). *A Course in Functional Analysis*. Springer-Verlag, New York, second edition.

[5] Ljubič, J. I. and Macaev, V. I. (1965). On operators with a separable spectrum. *Amer. Math. Soc. Transl. (2)*, 47:89–129.

[6] Read, C. J. (1985). A solution to the invariant subspace problem on the space l_1. *Bull. London Math. Soc.*, 17:305–317.

Appendix A

Inertial Measurement Units

Inertial Measurement Units

Accelerometer

Angular rate gyroscope

Magnetometer

Inertial Sensor Signal

The IMU signal

Kinematic Parameters

Coordinate Systems

Benchmark

Shimmer3 (Dublin, Ireland)

BtStream firmware program is used for shimmer configuration and data capture over Bluetooth. The Shimmer unit is within Bluetooth range of the PC (<12m approximately).
rechargeable Lithium Polymer battery 3.7V 450mAh

Capabilities

According tot he User Guide, the output data of the sensors are approximate values

Low Noise Accelerometer A KXRB5-2042 device from Kionix is used

- Zero-output: 1.5 V.
- Full scale range: ±2.0 g.
- Sensitivity: 600 mV/g.

Wide Range Accelerometer SM303DLHC device from STMicro

- Full scale range: ±2.0 g; ±4.0 g; ±8.0 g; ±16.0 g.
- Sensitivity (LSB/g): 1000 (±2.0 g); 500 (±4.0 g); 250 (±8.0 g); 83.3 (±16.0 g).
- Output: 16 bits

The gyroscope on the MPU-9150 chip from Invensense

- Full scale range (deg/sec): ±250; ± 500; ±1000; ±2000.
- Sensitivity (LSB/(deg/sec)): 131 (±250); 65.5 (±500); 32.8 (±1000); 16.4 (±2000).
- Output: 16 bits.

magnetometer LSM303DLHC device from STMicroelectronics

- Full scale range (Ga): ±1.3; ±1.9; ±2.5; ±4.0; ±4.7; ±5.6; ±8.1.
- Sensitivity (X,Y/Z) (LSB/Ga): 1100/980 (±1.3); 855/760 (±1.9); 670/600(±2.5); 450/400 (±4.0); 400/355(±4.7); 330/295 (±5.6); 230/205 (±8.1).
- Output: 16 bits

Noise performance when varying signal bandwidths . the sampling rate for each case was 500 Hz with a low-pass filter for the variation of the bandwidth.

Bandwidth (Hz)	50	100	250
Low Noise Accelerometer RMS noise (m/s^2)	3.51×10^{-3}	5.09×10^{-3}	8.12×10^{-3}
Wide Range Accelerometer RMS noise (m/s^2)	18.6×10^{-3}	27.5×10^{-3}	37.2×10^{-3}
Gyroscope RMS noise (deg/s)	0.0322	0.0481	0.0785
Magnetometer RMS noise (normalised local flux)	0.005	0.0081	0.0129

For further information, please refer to the manufacturer's datasheets.

9 Degrees of Freedom - Razor IMU

Capabilities

triple-axis Digital accelerometer ADXL345 device from Analog Devices.

- Full scale range: ±2.0 g; ±4.0 g; ±8.0 g; ±16.0 g.
- Sensitivity (LSB/g): Min232, Typ256, Max286 (±2.0 g); Min116, Typ128, Max143 (±4.0 g); Min58,Typ64, Max71 (±8.0 g); Min29,Typ32, Max36 (±16.0 g).
- Output: User-selectable resolution: 10-bit or 13-bit

Noise Performance x-,y-Axes. Date rate = 100 Hz for ±2 g, 10-bit. <1.0 LBS rms z-Axes. Date rate = 100 Hz for ±2 g, 10-bit. <1.5 LBS rms

The gyroscope on the ITG-3200 chip from Invensense

- Full scale range (deg/sec): ±2000.
- Sensitivity (LSB/(deg/sec)): 14.375 (±2000).
- Output: 16-bit

Gyro Noise performance
Total RMS noise. 100Hz LPD (DLPFCFG=2). 0.38 deg/sec-rms
Rate Noise Spectral Density. At 10Hz. 0.03 deg/sec $\sqrt{Hz}$

magnetometer. HMC5883L device from Honeywell

- Full scale range (Gauss): ±8.
- Sensitivity (LSB/Gauss): Min230,Max1370 (±8)
- Output: 12-bit ADC

Noise Floor (Field resolution) VDD=3.0V, GN=0, No measurement average, Standard Deviation 100 samples. Typ: 2 milli-gauss. https://www.sparkfun.com/products/10736

IMU WAX9 sensor from axivity (Newcastle, UK)

The devices are £149.00 each (excluding VAT). plus delivery charge of £9.99

Physical Parameter: Dimensions 23x32.5x7.6 (mm) Weight 7g

Typical Capabilities

Accelerometer: ± 2 / 4 / 8g (14 bit resolution). Range setting Convert to g Dynamic range 2 divide by 16384 ± 2g 4 divide by 8192 ± 4g 8 divide by 4096 ± 8g

Gyro: ± 250 / 500 / 2000 dps (16 bit resolution) Range setting Convert to deg/sec Dynamic range 250 multiply by 0.00875 ± 250 dec/sec 500 multiply by 0.01750 ± 500 dec/sec 2000 multiply by 0.07000 ± 2000 dec/sec

Magnetometer: ± 1uT steps (1 mGs, milli-gauss). (16 bit resolution) The range of the sensor is ± 20,000 (2 mT or 0.2 Gs).

Temperature Range: 0 - 65 °C (0.1°C resolution) Pressure: 30-110 kPA (1Pa resolution)

Battery Life: Hibernate 56 days LE Connected (50Hz stream) 6 Hours

Sample rate: The data rate is set by the RATEX variable in samples per second (default 50 Hz).

The sensors on the WAX9 are all digital sensors with their own independent sample clocks.

The sensors each have their own independent internal sample rates because of the sampling scheme described above. Variable Values Effect Accelerometer rate 12 50 100 200 400 800 Internal rate Hz Accelerometer range 2 4 8 Range in +/-g Gyroscope rate 100 200 400 800 Internal rate Hz Gyroscope range 250 500 2000 Range in dps Magnetometer rate 5 10 20 40 80 Internal rate Hz

http://axivity.com/userguides/wax9/technical/

WAX9 has different operating sample frequencies which is considered to be booth as a disadvantage and adtange.

IMU EXL-S3 sensor from exel (Bologna, Italy)

EXLs3 1 to 9 pieces for Euros 230 each. EXLs3KIT1 1 to 9 pieces for 384

*Features

Module size 54 mm x 33 mm x 14 mm Module weight 22 g 32-bit MCU, Cortex-M3 @72 MHz 3-axis accelerometer with selectable full-scale range (±2 / ±4 / ±8 / ±16 g). 3-axis gyroscope with selectable full-scale range (±250 / ±500 / ±1000 / ±2000 dps) 3-axis magnetometer ±1200 dps Orientation estimation with Kalman filtering and quaternion output. Sampling rate up to 200 Hz for raw data and 100 Hz for orientation data. Various data packet format available BluetoothTM 2.1 class 1. Up to 7 nodes at the same time can stream data to the same host. 1GB Flash Memory (USB Mass Storage) for data storage Docking station with micro-USB connector for battery recharging and log-file downloading. Battery operating time 3h

SAMPLE RATE

200 Hz (100 Hz if a packet with orientation is chosen) 100 Hz 50 Hz 33.33 Hz 25Hz 20Hz 16.67 Hz 12.5 Hz 10 Hz 5 Hz 300 Hz (No magnetometer data, 100 Hz if a packet with orientation is chosen)

Odroid myAHRS+

£69.52 Ex Tax: £57.93 We offer free shipping (delivery up to 5 working days) to all UK destinations.

myAHRS+ is a high performance AHRS(Attitude Heading Reference System).

the following connectivity options are available: - USB : Virtual COM PORT - UART : Standard baud rates up to 460800 bps - I2C : up to 1kHz

Unfortunately we are unable to offer technical support on the ODROID range of products. Clive - Lilliput UK

* Sensors - Triple axis 16-bit gyroscope : ± 2000 dps - Triple axis 16-bit accelerometer : ± 16 g - Triple axis 13-bit magnetometer : ± 1200 uT

* On board software - Exteneded Kalman filter - max 100 Hz output rate Attitude : Euler angle, Quaternion Sensor : acceleration, rotation rate, magnetic field

user-programmable gyro full-scale range of ±250, ±500, ±1000, and ±2000°/sec (dps) Gyro sensitivity (LSB/°/sec) N/A Gyro Rate Noise (dps/ Hz) 0.005

a user-programmable accelerometer full-scale range of ±2 g, ±4 g, ±8 g, and ±16 g, Accel Sensitivity (LSB/g) N/A and compass with a full scale range of ±1200 uT.

A.1 benchmark

Sensor	Price*	Connectivity	ACC	GYR	MAG	Sample rate Hz	Temp.	battery time	API
9 DOF Razor	£59.99	USB,Bluetooth 2.1, LE	Full-scale range: ± 2 g Sensitivity: 256 LSB/g ADCs: 10-bit	Full-scale region: ±2000 dps Sensitivity: 14.375 LSB/dps ADCs: 16-bit	Full-scale region: ±8 Gauss Sensitivity: 230 to 1370 LSB/gauss ADCs: 12-bit	50	–	–	C++ Android ROS
myAHRS+	£69.52	USB,UART,I2C	Full-scale Range: ±16 g Sensitivity: (2048 LSB/g) ADCs: 16-bit	Full-scale region: ±2000 dps Sensitivity: 16.4 LSB/dps ADCs: 16-bit	Full-scale Range: ± 1200 T Sensitivity: 0.3 T/LSB ADCs: 13-bit	max 100	-40 to +85°C Res: 340 LSB/°C	–	C++ Python ROS
EXLs3	384 euro ≈ £291	Bluetooth 2.1	Full-scale range: ± 2/ 4/8/16 g	Full-scale range: ± 250/ 500/1000/2000 dps	Full-scale range: ±1200 dps	5, 10, 12.5, 16.67, 20, 25, 33.33, 50, 100, 200, 300	–	3h	–
WAX9	£178.8	Bluetooth 2.1 and LE	± 2/4/8g Resolution: 14-bit	± 250/500/2000 Resolution: 16-bit	Range ± 1mT Resolution: 16-bit	1 to 400	0 - 65°C	6h	C# iOS App
Shimmer3	503.07 euro ** ≈ £381	USB,Bluetooth 2.1	± 2/4/8/16 g Sensitivity: 1000(2g) /500(4g)/250(8g)/ 83.3(16g) LSB/g ADCs: 16-bit	Range: ± 250/500/ 1000/2000 Sensitivity: 131(250) / 65.5 (500) 32.8(1000) / 250 (2000)LBS/g ADCs: 16-bit ADCs: 16-bit	Range: ±1.3/1.9/2.5/4.0/ 4.7/5.6/8.1 Ga Sensitivity (X,Y/Z) (LSB/Ga): 1100/980(1.3), 855/760(1.9) 670/600(2.5), 450/400(4.0) 400/355(4.7), 330/295(5.6) 230/205 (8.1) ADCs: (16 bits)	10.24 to 1024	–	14h15m (@51.2Hz)	Matlab LabVIEW C# Android

*Incl. Tax, ** Incl. shipping *** g is the acceleration due to gravity

Appendix B

How to install LaTeX

Windows OS

TeXLive package - full version

1. Download the TeXLive ISO (2.2GB) from
   https://www.tug.org/texlive/
2. Download WinCDEmu (if you don't have a virtual drive) from
   http://wincdemu.sysprogs.org/download/
3. To install Windows CD Emulator follow the instructions at
   http://wincdemu.sysprogs.org/tutorials/install/
4. Right click the iso and mount it using the WinCDEmu as shown in
   http://wincdemu.sysprogs.org/tutorials/mount/
5. Open your virtual drive and run setup.pl

or

Basic MikTeX - TeX distribution

1. Download Basic-MiKTeX(32bit or 64bit) from
   http://miktex.org/download
2. Run the installer
3. To add a new package go to Start » All Programs » MikTex » Maintenance (Admin)
   and choose Package Manager

4. Select or search for packages to install

TexStudio - TeX editor

1. Download TexStudio from
   http://texstudio.sourceforge.net/#downloads

2. Run the installer

Mac OS X

MacTeX - TeX distribution

1. Download the file from
   https://www.tug.org/mactex/

2. Extract and double click to run the installer. It does the entire configuration, sit back and relax.

TexStudio - TeX editor

1. Download TexStudio from
   http://texstudio.sourceforge.net/#downloads

2. Extract and Start

Unix/Linux

TeXLive - TeX distribution

Getting the distribution:

1. TexLive can be downloaded from
   http://www.tug.org/texlive/acquire-netinstall.html.

2. TexLive is provided by most operating system you can use (rpm,apt-get or yum) to get TexLive distributions

Installation

1. Mount the ISO file in the mnt directory

   ```
   mount -t iso9660 -o ro,loop,noauto /your/texlive####.iso /mnt
   ```

2. Install wget on your OS (use rpm, apt-get or yum install)

3. Run the installer script install-tl.

   ```
   cd /your/download/directory
   ./install-tl
   ```

4. Enter command 'i' for installation

5. Post-Installation configuration:
   http://www.tug.org/texlive/doc/texlive-en/texlive-en.html#x1-320003.4.1

6. Set the path for the directory of TexLive binaries in your .bashrc file

For 32bit OS

For Bourne-compatible shells such as bash, and using Intel x86 GNU/Linux and a default directory setup as an example, the file to edit might be

```
edit $~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/i386-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

For 64bit OS

```
edit $~/.bashrc file and add following lines
PATH=/usr/local/texlive/2011/bin/x86_64-linux:$PATH;
export PATH
MANPATH=/usr/local/texlive/2011/texmf/doc/man:$MANPATH;
export MANPATH
```

```
INFOPATH=/usr/local/texlive/2011/texmf/doc/info:$INFOPATH;
export INFOPATH
```

Fedora/RedHat/CentOS:

```
sudo yum install texlive
sudo yum install psutils
```

SUSE:

```
sudo zypper install texlive
```

Debian/Ubuntu:

```
sudo apt-get install texlive texlive-latex-extra
sudo apt-get install psutils
```

Appendix C

Installing the CUED class file

LaTeX.cls files can be accessed system-wide when they are placed in the <texmf>/tex/latex directory, where <texmf> is the root directory of the user's TeXinstallation. On systems that have a local texmf tree (<texmflocal>), which may be named "texmf-local" or "localtexmf", it may be advisable to install packages in <texmflocal>, rather than <texmf> as the contents of the former, unlike that of the latter, are preserved after the LaTeXsystem is reinstalled and/or upgraded.

It is recommended that the user create a subdirectory <texmf>/tex/latex/CUED for all CUED related LaTeXclass and package files. On some LaTeXsystems, the directory look-up tables will need to be refreshed after making additions or deletions to the system files. For TeXLive systems this is accomplished via executing "texhash" as root. MIKTeXusers can run "initexmf -u" to accomplish the same thing.

Users not willing or able to install the files system-wide can install them in their personal directories, but will then have to provide the path (full or relative) in addition to the filename when referring to them in LaTeX.

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