A Multi-Sensory Inertial Measurement Unit Dataset for Fetal Condition Monitoring

Rahal Nanayakkara[1], Isuru Thilakasiri[1,*], Praditha Alwis[1], Roshan Godaliyadda[1], Parakrama Ekanayake[1], Janaka Wijayakulasooriya[1], and Chathura Ratnayake[2]

[1]Department of Electrical and Electronic Engineering, Faculty of Engineering, University of Peradeniya
[2]Department of Obstetrics & Gynaecology, Faculty of Medicine, University of Peradeniya,
[*]Corresponding Author Email: isurupt@eng.pdn.ac.lk

ABSTRACT

One of the most prevalent methods for assessing the health of a fetus is through fetal movement count monitoring. Mothers are advised by doctors to measure and monitor fetal movements and the manual counting technique based on mothers' perception is unreliable. Utilizing equipment like ultrasound scanners to better identify the features is only permitted in clinical environments. Thus, comprehensive systems that can allow expectant mothers to track fetal activity at home are important. For this task, wearable sensory devices are being evaluated and the use of an inexpensive sensor that is non-intrusive and non-transmitting alongside the processing component for the identification of the events was used for the collection of this dataset. The use of four inertial measurement sensors was combined with a microcontroller-based circuit for the device manufactured and the clinical testing was conducted utilizing the above-mentioned sensor unit. An ultrasound scan of the abdomen was used as the main ground truth during the validation process and the mothers' perception labels were also considered as a form of ground truth in some instances. This variety of ground truths of the dataset allows the researchers to evaluate the validity of both ultrasound fetal movement monitoring and mothers' perception.

Data Description

- **Study type (e.g. experimental, case control, cohort, descriptive etc)** - Experimental Clinical Data Analysis

- **Ethical Clearance:** This study was approved by the Ethics Review Committee, Faculty of Medicine, University of Peradeniya. Approval was granted to conduct research project No. 2018/EC/43 entitled "Fetal movement analysis for condition monitoring" at the Teaching Hospital, Peradeniya, Sri Lanka.

- **Clearly defined population & sample**

  - Pregnant mothers from all 3 trimesters
  - Non pregnant females with matched BMI as a control group

- **Sample size** - 44 pregnant mothers (30 Ward readings, 14 Ultrasound readings)

  Ultrasound Readings refer to the subject recordings with Ultrasound observations as the ground truth.

  Ward Readings refer to the subject recordings with mothers' perception ground truths.

- **Data Format** - The data file format is Comma Separated Value (CSV), where the top row contains the column names; an example data file is shown in figure 1. Some column names are described in Table 1, and the other column names follow the same format.

  File names Ui_j refers to the j^{th} recording of the i^{th} subject who participated in the ultrasound study.

  File names Wi_j refers to the j^{th} recording of the i^{th} subject who participated in the ward study.

Name	Description
time	Time in seconds since the start of the recording
axi	Accelerometer reading in the x-axis of the i^{th} IMU
gyj	Gyroscope reading in the y-axis of the j^{th} IMU
state	Ground-truth label

Table 1. Column Description

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	time	ax1	ay1	az1	gx1	gy1	gz1	ax2	ay2	az2	gx2	gy2	gz2	ax3	ay3	az3	gx3	gy3	gz3	ax4	ay4	az4	gx4	gy4	gz4	state
2	0	-1188	-13144	11252	624	-258	37	-8172	1144	9260	661	-239	32	-3840	-13048	8512	512	256	0	-3328	256	8448	528	-256	32	0
3	32689	-1116	-13092	11260	608	-254	43	-9404	1120	10240	580	-268	0	-3184	-13052	8192	616	232	18	-3536	272	8364	578	77	1	0
4	63961	-1076	-13148	11068	600	-393	-5	-7936	1040	10240	558	-384	4	-3200	-13304	8192	513	0	185	-3768	224	8384	528	13	40	0
5	95230	-932	-13084	11208	579	-413	25	-7936	1188	10256	518	-494	12	-3164	-13304	8260	512	12	17	-2816	100	8200	512	4	2	0
6	126552	-1052	-13116	11212	592	-316	13	-8188	1216	10256	8	-383	8	-4064	-13272	8324	513	36	25	-3840	32	8196	57	4	36	0
7	157825	-1044	-13020	11248	484	-350	66	-8056	1064	10304	1	-380	4	-3248	-13304	8336	256	38	48	-3688	8	8320	522	8	68	0
8	189104	-1116	-13076	11136	471	-308	76	-9424	1032	10248	464	-382	39	-4064	-13184	8336	256	65	0	-3576	16	8232	142	88	17	0
9	220380	-1144	-13100	11096	543	-356	-5	-8096	1088	10244	512	-384	-112	-3184	-13056	8224	545	18	169	-3648	0	8448	580	11	644	0
10	251852	-1088	-13120	11220	577	-338	3	-8184	1104	10240	576	-459	-110	-3200	-13272	8324	536	33	6	-3712	72	8512	532	33	9	0
11	283129	-1072	-13040	11168	553	-353	31	-7872	1088	10384	33	-380	2	-4084	-13280	8448	513	64	100	-3840	80	8448	516	43	1	0
12	314403	-1096	-12992	11220	585	-344	23	-7936	1032	10240	4	-384	9	-4048	-13240	8200	522	8	1	-3776	224	8480	528	74	22	0
13	345677	-1064	-13188	11116	537	-385	1	-8040	1096	9144	32	-341	18	-3120	-13280	8256	513	64	1	-3772	88	8464	514	-379	26	0
14	377136	-1080	-13076	11280	629	-318	1	-8160	1064	10252	98	-336	1	-3196	-13056	8212	536	49	0	-3712	160	8456	520	-316	0	0
15	408411	-1208	-13008	11176	591	-274	6	-8160	1040	10240	72	-288	2	-3136	-13056	11236	514	32	8	-3696	0	8216	552	0	626	0
16	439685	-1128	-12996	11184	598	-297	-38	-8176	1216	10284	43	-352	-207	-3312	-13280	8208	514	1	5	-3840	0	8544	134	12	512	0
17	470962	-1176	-13192	11244	625	-333	-28	-8188	1184	10240	1	-441	-127	-3328	-13120	8256	641	38	64	-3824	16	8488	514	0	609	0
18	502231	-960	-13096	11124	658	-287	28	-8128	1152	10240	0	-311	-134	-3840	-13152	8196	650	32	8	-2988	256	8448	520	-287	2	0
19	533621	-956	-13192	11060	662	-316	13	-7936	1312	10272	32	-320	40	-4088	-13304	8240	523	192	0	-3780	160	8464	524	-270	36	0
20	564899	-992	-12872	11216	555	-323	58	-8184	1232	10240	16	-331	1	-3160	-13304	11104	546	164	30	-3828	0	8604	512	16	69	0
21	596178	-1096	-12980	11320	615	-285	94	-7936	1064	10280	20	-383	16	-4088	-13056	8216	537	153	64	-3804	64	8200	553	3	80	0
22	627456	-768	-13020	11192	542	-378	87	-8032	1280	10240	556	-472	9	-3140	-13136	8388	520	128	1	-3832	108	8456	516	0	64	0
23	658780	-1088	-13184	11188	536	-376	58	-9260	1280	10256	4	-431	42	-4064	-13120	8368	512	44	28	-3840	4	8236	50	48	16	0
24	690060	-1128	-12952	11280	528	-406	35	-8128	1248	10240	552	-442	0	-3840	-13176	8192	549	20	1	-3776	4	8264	534	0	9	0
25	721335	-996	-13008	11172	563	-335	1	-8064	1280	9128	534	-358	36	-3192	-13104	8208	528	48	25	-3856	0	8712	517	64	20	0
26	752605	-972	-13092	11348	510	-312	20	-7976	1280	10336	480	-320	49	-3228	-13240	8192	512	8	4	-3840	4	8580	128	-348	48	0
27	784063	-1168	-12956	10984	524	-323	19	-9272	1168	10304	520	-376	0	-3136	-13304	11104	512	9	8	-3768	148	8448	512	26	2	0
28	815342	-1064	-13112	11328	522	-358	12	-8064	1200	10260	512	-384	-155	-3152	-13056	8200	512	0	6	-3056	0	8324	562	26	4	0
29	846614	-1048	-13116	11212	577	-327	26	-8064	1200	10304	525	-312	41	-3840	-13292	11080	576	0	4	-3912	200	8368	560	2	0	0
30	877886	-1052	-13144	11216	567	-289	81	-8060	1152	10468	516	-286	17	-3200	-13308	8224	528	163	4	-3056	268	8200	537	65	34	0
31	909320	-1056	-13200	11088	568	-337	46	-8156	1216	10496	528	-380	1	-4072	-13056	8244	538	17	15	-3068	128	8544	512	3	16	0

Figure 1. Example Data File

- **ward_Readings.csv** - Contains information about the recordings with mothers' perception ground truths (shown in figure 2).
- **ultrasound_Readings.csv** - Contains information about the recordings with Ultrasound observations as the ground truth (shown in figure 3).
- **Sampling technique** - Depending on the trimester and weight class of the pregnant mothers.
- **Inclusion and exclusion criteria** - Pregnancy
- **Detailed randomization technique where appropriate** - Maximizing the inclusion of different age groups, BMI values and Gestational Age.
- **Details of the blinding technique and data collection method** - No blinding technique is used, as the gathered data will be used for the validation of readings collected from the prototype device. Data will be gathered from pregnant mothers admitted to the professorial ward of the department of gynecology and obstetrics, University of Peradeniya.

ward_Readings

File Edit View Insert Format Data Tools Extensions Help

A1 recording

	A	B	C	D	E	F	G	H	I	J
1	recording	participant_no	duration	weight	height	age	gestational_age	no_of_babies	previous_pregnancies	comments (miscarrages/ stillbirth/ other health conditions)
2	W01_R1	1	1363	66	145	29	223	2	0	
3	W02_R1	2	1266	75	153	29	240	2	3	
4	W03_R1	3	1212	70	157.5	24	275	1	0	
5	W04_R1	4	259	62	152	24	266	1	0	
6	W04_R1	4	783	62	152	24	266	1	0	
7	W05_R1	5	1242	61.5	150	30	283	1	1	
8	W05_R2	5	19	61.5	150	30	283	1	1	
9	W06_R1	6	1238	67	152	26	266	1	0	
10	W07_R1	7	905	58	162	25	281	1	0	High Sugar
11	W08_R1	8	916	60	145	35	259	1	1	
12	W09_R1	9	1263	62	153	26	280	1	0	
13	W10_R1	10	1292	68	152	36	266	1	0	
14	W11_R1	11	592	72	160	25	280	1	1	
15	W11_R2	11	42	72	160	25	280	1	1	
16	W11_R3	11	272	72	160	25	280	1	1	
17	W11_R4	11	379	72	160	25	280	1	1	
18	W11_R5	11	214	72	160	25	280	1	1	
19	W12_R1	12	1394	62	152	45	280	3	0	
20	W13_R1	13	1006	80	165	28	232	1	1	
21	W14_R1	14	674	67	162	30	281	1	1	
22	W15_R1	15	493	48.5	146	28	277	1	0	Abdominal Pain & Can not feel much fetal movement. visited the ward after work.
23	W15_R2	15	478	48.5	146	28	277	1	0	Abdominal Pain & Can not feel much fetal movement. visited the ward after work.
24	W16_R1	16	1201	50	150	25	266	1	0	
25	W17_R1	17	1286	70	153	28	280	1	0	
26	W18_R1	18	662	46	154	29	281	1	0	
27	W19_R1	19	830	67	155	28	282	1	0	
28	W20_R1	20	914	63	165	30	266	1	0	
29	W21_R1	21	718	75	152	28	267	1	1	C-Section. Reading was taken the day before delivery

Figure 2. ward_Readings.csv

ultrasound_Readings

File Edit View Insert Format Data Tools Extensions Help

A1 recording

	A	B	C	D	E	F	G	H	I	J
1	recording	participant_no	duration	weight	height	age	gestational_age	no_of_babies	previous_pregnancies	comments (miscarrages/ stillbirth/ other health conditions)
2	U01_R1	1	743	57.2	160	33	280	1	0	Very Active Baby
3	U02_R1	2	428	81.5	155	38	266	1	2	Breathing difficulties, Cough, Hypertension
4	U02_R2	2	561	81.5	155	38	266	1	2	Breathing difficulties, Cough, Hypertension
5	U03_R1	3	951	65	150	27	280	1	0	
6	U04_R1	4	1031	70	168	31	280	1	1	No fetal movement felt by mother
7	U05_R1	5	792	55	154.5	28	280	1	0	
8	U06_R1	6	740	51.5	159	27	249	1	0	Cardiac murmur & the baby showed no movements the day before the recording date
9	U07_R1	7	891	50.5	146.5	27	271	1	0	Hypertension
10	U08_R1	8	591	70	159.5	32	280	1	0	
11	U08_R2	8	286	70	159.5	32	280	1	0	
12	U09_R1	9	270	59	160	28	272	1	1	One Stillbirth
13	U09_R2	9	340	59	160	28	272	1	1	One Stillbirth
14	U10_R1	10	736	57	154	24	252	1	0	
15	U11_R1	11	646	60	162	28	259	1	1	Cholesterol
16	U12_R1	12	37	63	156	27	252	1	1	Nausea
17	U12_R2	12	94	63	156	27	252	1	1	Nausea
18	U12_R3	12	163	63	156	27	252	1	1	Nausea
19	U12_R4	12	70	63	156	27	252	1	1	Nausea
20	U12_R5	12	94	63	156	27	252	1	1	Nausea
21	U13_R1	13	622	67	160	26	266	1	0	
22	U14_R1	14	562	70	158	32	259	1	2	Sugar
23	U14_R2	14	74	70	158	32	259	1	2	Sugar

Figure 3. ultrasound_Readings.csv

- **A detailed list of study variables**
  - Date
  - Starting Time
  - Ending Time
  - Number of Babies
  - Number of previous pregnancies
  - Number of Miscarriages
  - Fetal Movement Types
  - BMI Value
  - Mothers Age
  - Gestational Age
  - Other complication details
- **This dataset was collected to have a good variety in the data and the considered variables. A brief description of the data distribution is given below. This information is also provided alongside each recording. Refer to ward_Readings.csv and ultrasound_Readings.csv .**
  - Mothers with Single, Twin, Triplet pregnancies participated in the study.
  - Mothers that expected both Cesarean (C-section) & Vaginal deliveries participated in the study.
  - A considerable portion of the participants had belonged to reduced fetal movement categories, which helps to process and evaluate the algorithms in a fail safe manner.
  - Mothers who had Miscarriages, Stillbirths before also participated in the study.
  - Mothers conditions with abnormal abdominal pain also participated in the study.
  - Recording other conditions of the mothers such as Sugar and other complications was done so that one can analyse those recordings separately if needed for some other task.
  - Other artifacts such as Cough, Positional changes, Laughs were also recorded. This was done to differentiate between the fetal movements from other movements as the sensors used in the device are sensitive to both events and these artifacts could be mistaken as fetal movements.
  - Mothers who participated in the study were from a wide range of BMI Values
  - The gestational age and mothers age also had a good distribution. Mothers of all ages from 23 year old to 36 year old participated in the study except for the ages 27, 33, 34. Only participant that did not belong in this age group was a mother of 45 years old and all these information is recorded in the information sheets inside the dataset.

Instrument

Four IMU sensors were used as non-invasive sensors to capture fetal movement vibrations in the maternal abdomen. Each sensor outputs 3 accelerometer readings and 3 gyroscope readings. The device had several modes of operation and it can be identified using figure 4. The completed device is shown by figure 5.

- **Start/Stop** - Power ON and OFF

- **Pos** - Record if the mother has made any sudden movements during the recording process, as it is needed to be filtered to properly not label other abdominal movements as fetal movements.

- **Laugh** - Record if the mother laughed during the recording process, as it is needed to be filtered to properly not label other abdominal movements as fetal movements.

- **Cough** - Record if the mother coughed during the recording process, as it is needed to be filtered to properly not label other abdominal movements as fetal movements.

- **M1 to M4** - These buttons can be used to capture upto 4 different fetal movements such as limb, tunk, general body or these can be attributed to the four quadrants of the belly as well if needed.

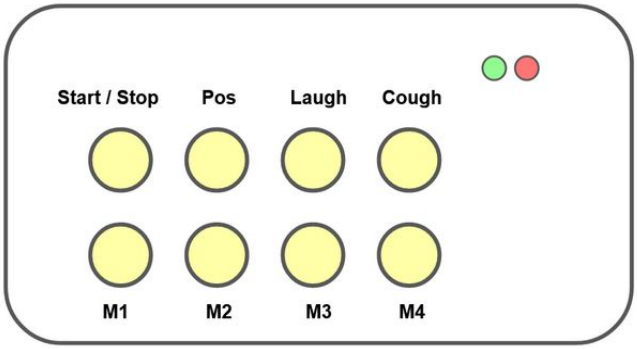

Figure 4. Device Layout

Figure 5. The Completed Device

Acknowledgements

We would like to express our sincere gratitude to all the staff members of the maternity ward of Peradeniya Teaching Hospital, Sri Lanka. Our special thank goes to the ward doctors and ward sisters for assisting us in data collection.