Extracting Gait Parameters from Raw Data Accelerometers

André DIAS[a,b,c,1], Lukas GORZELNIAK[b], Angela DÖRING[c], Gunnar HARTVIGSEN[a,d], Alexander HORSCH[b,d]

[a] *Norwegian Centre for Integrated Care and Telemedicine, University Hospital of North Norway, Tromsø, Norway*

[b] *Institut für Medizinische Statistik und Epidemiologie, Technische Universität München, Germany*

[c] *Institute of Epidemiology, Helmholtz Zentrum München, Germany*

[d] *Computer Science Department, University of Tromsø, Norway*

Abstract Spatiotemporal gait parameters are very important for the detection of gait impairments and associated conditions. Current methods to measure such parameters, like e.g. electronic walkways or force plates, are costly and can only be used in a laboratory. The new generation of raw data accelerometers might be a cheap and flexible alternative. We conducted a small feasibility study with 50 subjects from the KORA-Age project comparing the output of GAITRite and Actigraph GT3X. We open-sourced a package to extract and process such data. Our results show that it is possible to extract, from GT3X data, parameters similar to the ones provided by GAITRite. The most promising location for the accelerometer seems to be at the ankle. The use of accelerometers showed to be simple and reliable, indicating that they can be used on daily living to extract gait parameters.

Keywords. Gait parameters, Actigraph GT3X, GAITRite, open source

Introduction

Objective measurements of spatiotemporal gait parameters are essential in a clinical or research environment to detect possible gait impairments or to monitor the effects of recovery therapy.

There are several methods for the assessment of gait parameters, varying in validity, reliability and usability, such as force plates, pressure activated sensors and motion analyses from video. Most of them are either costly, time or labor intensive, or can only be applied to few gait cycles. Because of these limitations they are only feasible in a laboratory, raising the question if such data represents the gait performance in daily life [1]. For these reasons, a portable and easy to use method is of great value, as it allows measurements for many gait cycles in daily living.

In the last years, accelerometer-based gait analysis systems have been proposed for this task [2,3]. Present technology allows us to record data in very high frequencies for long periods, opening a promising window for portable gait assessment. The elderly

[1] Corresponding author: André Dias IFI, UiT 9037 Tromsø, Norway. E-mail: andre.dias@uit.no

population is an essential target group. However, so far little work has been done on applying accelerometers for gait assessment within this group [4].

1. Materials and methods

1.1. Sensors

For assessment of the gait parameters we used the GAITRite portable electronic walkway (CIR Systems Inc., Havertown, USA), 6 meters long, measurement length 4.88 meters, and 0.89 meters wide, with a sampling rate of 80 Hz.

For motion sensing we used sets of 4 triaxial accelerometers of type Actigraph GT3X (Actigraph LLC, Ford Walton Beach, Florida, USA) with 16MB and capable of recording data at 30 MHz. This accelerometer has been validated in several published studies for medical and epidemiological research.

1.2. Subjects

We asked a subset of 50 subjects recruited for the KORA-Age project [5] to additionally wear the accelerometers while walking in the GAITRite, which was part of the KORA-Age study protocol, with no changes due to the accelerometers. The subset was selected by asking every subject that took part in the KORA-Age project at randomly selected days. Therefore the same inclusion and exclusion criteria of KORA-Age study applied [5].

The accelerometers were prepared and attached by the biosensor team, subjects were given a brief explanation of the goal and asked to performed four walks (normal walk, slow walk, fast walk, and walk performing a mental task). The acceptance rate was 100%, i.e. all subjects agreed in wearing the sensors.

1.3. Data acquisition and handling of GT3X

Each subject wore one tri-axial sensor at each of the extremities: left and right wrist, left and right ankle. The sensors were configured for raw data mode recording. Care was taken by customizing Velcro straps in order to ensure reliable sensor attachment and correct orientation.

Time constraints of the KORA-Age protocol did not allow download and reconfiguration of the sensors for each subject. So, each sensor recorded the entire day, without breaks, merging data from several subjects in one session/file. We used one computer for operating Gaitrite and GT3X, to ensure synchronization.

1.4. Data processing

1.1.1. Data from GAITRite

The main software application provided by the manufacturer is proprietary. Therefore it was not possible to extend the methods and gait parameters extracted from the data.

However, the vendor provides a separate program named Gaitraw, which outputs the raw data in a known format, documented by CIR Systems and made available to us.

We developed an open-source Java package to process the data provided by Gaitraw. First, as shown in Table 1, seven gait parameters equivalent to those computed by the GAITRite were implemented, in order to create a testing ground. Later we extended this set of features by one parameter that we found relevant for medical and epidemiological studies, as well as by a batch processing mode. Table 1 summarizes all extracted parameters. The software package, named GaitParser, is available for download and contribution at: http://code.google.com/p/gait-raw-parser/.

Table 1- Implemented parameters, at time of writing, in GaitParser.

Per walk	Ambulation time (AT)	Duration of the walk
Per footprint	Step length (SL)	Length of a step
	Side swing (SS)	Distance of a step from straight walking line (only GaitParser)
Per gait cycle	Gait cycle time (GT)	Duration of a gait cycle
	Single support (SP)	Duration of period only 1 foot on the ground
	Step time (ST)	Duration of a step
	Swing (SW)	Complementary to single support
	Double support (DS)	Time when both feet are on the ground

1.1.2. Data from Actigraph GT3X

Because the output of each GT3X sensor was one single CSV file including the measurements for all subjects of an entire day, we developed a script that takes the timestamps for each walk as input and splits the file into individual walks. It can process an arbitrary number of files in batch mode. Having the data for each walk, further processing was performed with a set of R statistics scripts. We performed data quality assurance tasks, visualization and statistical analysis of the data. This paper does not focus on modeling the gait parameters from the accelerometer data, as this is on going work.

2. Results

2.1. Comparison to GAITRite

In order to test the GaitParser software we randomly selected the data of 7 subjects from the study and did a direct comparison of the results to the GAITRite output. We got an error rate of less than 2% for the common gait parameters as shown in Table 2.

2.2. Output from Actigraph GT3X

Figure 1a shows the output from the GT3X sensor set mounted on both legs, for one subject, walking at a normal speed. We can clearly see the acceleration peaks resulting from the steps, in the X-axis (circled). Also identifiable are the time shifts between the two series of the same axis for left and right leg (arrow), indicating the alternate left and right steps. The Z-axis, capturing outward and inward movement, shows signals of low amplitude. We can observe a very stable acceleration pattern for each step, with regular amplitudes and durations.

The number of steps visually identifiable (4 for left leg and 5 for right leg) corresponds to the output from GAITRite for the same subject. There is a significant difference of amplitude for left and right X-axe, indicating gait impairment.

On Figure 1b we can see the matching data for the arms. It seems to contain equivalent information for gait analysis, but amplitudes appear lower than for the legs. The time shift in the series of the same component seems to be less visible in the arms than in the legs.

Table 2 - Errors in parameters between GaitParser and GAITRite.

Parameter	AT (s)	SL (cm)	GT (s)	SP (s)	ST (s)	SW (s)	DS (s)
Mean	2.85	78.32	1.10	0.48	0.56	0.48	0.20
Maximum error	0.00	0.01	0.02	0.00	0.01	0.00	0.00
Error Percentage	0%	0%	2%	0%	2%		0%

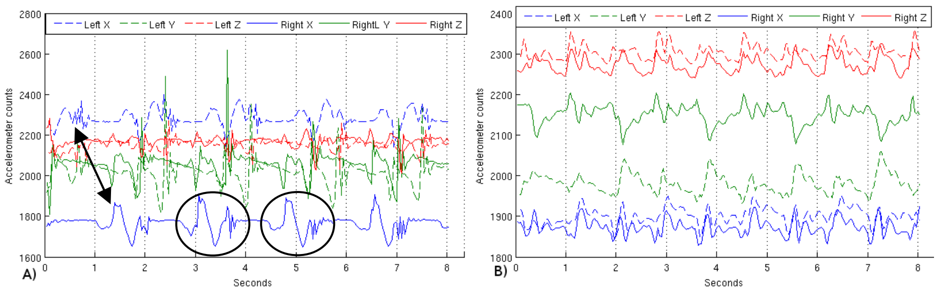

Figure 1 - Output from the GT3X sensors. a) leg sensors; b) arm sensors. Dotted: Left sensor. Full: Right sensor. Blue: X – axe. Green: Y-axe. Red: Z-axe. Arrow shows time shift. Circles show step pattern.

3. Discussion

The preliminary results we achieved from the GT3X sensors indicate that accelerometers capable of recording high frequency raw data may prove to be valuable tools for assessment of gait parameters during daily living. This had been explored in the published literature for young and adult populations. Our results indicate that we may expect similarly good results for elderly populations. The most promising location for mounting the motion sensors was the leg.

The lack of robust functionalities for batch processing and exporting of the calculated gait parameters, in the GAITRite system, makes it hard to use the data for further processing with other tools. Our approach based on open-source code is a first step in the direction to address these restrictions.

We were able to visually identify the key characteristics of the signal, leading us to believe that is possible to calculate robust gait parameters from the motion sensors. The ability of the sensors to record at high sample frequency provides us with enough information to explore pattern matching techniques to identify the key events of each gait cycle, quantifying all relevant parameters.

We do not present a direct comparison of the two systems, as it is a work still in progress. Thus, we can not make definitive statement if the use of raw data from accelerometers can in fact be successful. Given the easy of use and 100% acceptance by subjects in this study, we believe similar rates will be achieved in clinical application scenarios.

4. Conclusion

Further work is needed to improve the quantification of gait parameters from accelerometer data, in order to make the results reliable enough to be used for medical and epidemiological research. We are working on a complete software package capable of processing the data from GT3X in a simple and user friendly manner. We have also developed the infrastructure and collected reasonable amount of data to perform robust validation of the method against a de facto standard.

We want to encourage other researchers to explore and contribute to the GaitParser package as an open source research tool.

5. Acknowledgments

This research was funded/supported by the Graduate School of Information Science in Health (GSISH) and the Technische Universität München Graduate School. A. Dias is supported by scholarship SFRH/BD/39867/2007 of the Portuguese Foundation for Science and Technology and Research Council of Norway Grant No. 174934.

The authors wish to thank Jennifer Reinelt, Matej Svejda, Friederike Thun and Julia Strauß for their essential contributions to the project.

References

[1] Woollacott MH, Tang PF. Balance control during walking in the older adult: research and its implications. Phys Ther 1997;77:646–60.

[2] Kavanagh JJ, Menz HB. Accelerometry: a technique for quantifying movement patterns during walking. Gait Posture 2008;28:1–15.

[3] Henriksen M, Lund H, Moe-Nilssen R, Bliddal H, Danneskiod-Samsoe B. Test-retest reliability of trunk accelerometric gait analysis. Gait Posture 2004;19:288–97.

[4] de Bruin ED, Hartmann A, Uebelhart D, Murer K, Zijlstra W. Wearable systems for monitoring mobility related activities in older people; a systematic review. Clin Rehabil 2008;22:878–95.

[5] Holle R, Happich M, Löwel H, Wichmann HE; MONICA/KORA Study Group. KORA--a research platform for population based health research. Gesundheitswesen. 2005 Aug;67 Suppl 1:S19-25.