Combining Distance and Force Measurements to Monitor the Usage of Walker Assistive Devices

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***Abstract*—This paper presents a measurement system that can be used to monitor the usage of walker assistive devices. The forces applied on the legs of the walker device are measured using low cost force sensing resistors and a light detection and ranging device is used to evaluate several gait kinematic parameters, such as, walking speed and walking stride length. To evaluate the right usage of the walker device two walker indexes, one related with the applied forces and the other related with walker gait phases, are introduced. The measurement system includes wireless communication capabilities that enable a local and remote supervision of the measuring data.**

***Keywords*—walker assistive device; force measurements; distance measurements; kinematic parameters; walker risk indexes**

I. INTRODUCTION

Topics related with people mobility are already of major importance today and this importance will be even greater in the near future. Not only for patients, during recovery periods, but also, and above all, for elderly people, the usage of assistive walking devices can extend significantly their autonomy and quality of life. Regarding statistics and previsions, it is estimated that by 2025 in United States and Canada 25 % of the population will be aged over 65 years older [1-3]. Moreover, it is expected that in the European Union, for year 2060, the life expectance for women and men will be around 89 and 84.5 years, respectively [4]. In this context, it is important to refer that a proper usage of mobility aiding devices by elderly people can provide significant cost savings of health and long-term care systems [5-7]. However, it must be underlined that harmful injuries [8-9] can result from a bad usage of mobility aiding devices, being important to monitor its right usage. Thus, it is important to develop measurement solutions that can be used to monitor balance and stability conditions of users of mobility aiding devices. Several authors already studied measurement solutions for this purpose [10-14] but some solutions are complex, expensive and the added value of the additional information that can be accessed is questionable in terms of walker day-by-day applications. Moreover, several alternative systems include accelerometer sensors to extract kinematic parameters, like the ones related with human gait, and those sensors require the usage of complex algorithms to improve measurement data accuracy [15-16].

The main novelties that can be mentioned in the proposed measurement systems includes its low cost and easy adaptability to existing walker devices, the capability to extract kinematic parameters based on optical distance measurements, the capability to detect unbalance conditions and to detect, in real time, potential falling conditions. To obtain the experimental data, a prototype, based on a conventional walker with a four legs ground contact configuration, was implemented and used for testing purposes. It is important to refer that the measurement methods and technical solutions that are presented can be easily be applied to others mobility aiding devices, particularly, walkers with different ground contact configurations, namely wheeled walkers and rollators.

The paper is organized as follows: section two presents the proposed measurement solution and novelties; section three includes the hardware and software description of the measurement system; section four includes the experimental results and the last section, section five, draws the conclusions.

II. PROPOSED MEASUREMENT SOLUTION AND NOVELTIES

Considering the Cartesian plane associated with the coordinates of the pick-up walker legs, represented in Fig. 1, the center of pressure (COP) of the set of the four forces, each one associated with one leg of the walker device, is given by [17]:

$$COP_X = \frac{W_{12}\cdot(F_{L1}-F_{L2})+W_{34}\cdot(F_{L3}-F_{L4})}{2\cdot(F_{L1}+F_{L2}+F_{L3}+F_{L4})}$$
$$COP_Y = \frac{L\cdot[(F_{L1}-F_{L3})+(F_{L2}-F_{L4})]}{2\cdot(F_{L1}+F_{L2}+F_{L3}+F_{L4})} \quad (1)$$

where F_{Lk} represents the force applied in each walker leg, W_{12} and W_{34}, represent the distances between the pair of rear and front walker legs, respectively, that corresponds approximately to the walker width (W), and L represents the distance between the rear and front walker legs, that corresponds to the walker length.

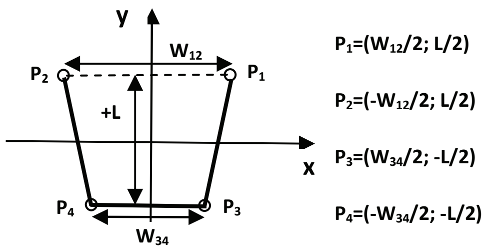

Fig. 1. Cartesian plane associated with the coordinates of the pick-up walker legs (L- distance between front and rear legs, W_{12}- distance between rear legs, W_{34}- distance between front legs).

The normalized deviation of the COP coordinates from the geometrical center of the polygon defined by the floor contacts of the walker legs can be used to define the following walker risk index:

rate or the increase of the oxygen consumption, that occur during the usage of every walker assistive device and additional field tests, with elderly people and patients with different diseases, are required to set a fine tuning between the walker risk indexes values and potential falling risks associated with loss of stability. It must also be underlined that besides centralized data processing of measurement data, self-warnings and alarms can also be signalized in the walker device if the walker indexes are out of their acceptance range, in terms of stability limits, or if their trend values are moving away from their average values, obtained from historical data.

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REFERENCES

[1] Carrie A. Werner (2010). "The Older Population: 2010" (PDF). 2010 Census Briefs. U.S. Census Bureau. C2010BR-09.

[2] Taylor, Albert W.; Johnson, Michel J. (2008). Physiology of Exercise and Healthy Aging. Human Kinetics. ISBN 978-0-7360-5838-4.

[3] "Population". 2008 Older Americans : Key indicators of Well-Being. 2008.

[4] European Commission, "Summaries of EU Legislation", Available at: http://europa.eu/legislation_summaries/employment_and_social_policy/situation_in_europe/c10160_en.htm [accessed Sept. 2014].

[5] S.R.Faruqui, T. Jaeblon," Ambulatory assistive devices in orthopaedics: uses and modifications", J Am Acad Orthop Surg. Issue 18, No. 1, p.p. 41–50, 2010.

[6] H. Bateni, B.E. Maki, "Assistive devices for balance and mobility: benefits, demands, and adverse consequences", Arch Phys Med Rehabil, Issue 86, No. 1, pp. 134–145, 2005.

[7] NTT data, Global IT Innovator, "Trends in Telehealth", Available at: http://americas.nttdata.com/Industries/Industries/Healthcare/~/media/Documents/White-Papers/Trends-in-Telehealth-White-Paper.pdf [accessed Sept. 2014].

[8] H. Bateni, B.E. Maki, "Assistive devices for balance and mobility: benefits, demands, and adverse consequences", Arch Phys Med Rehabil, Issue 86, No. 1, pp. 134–145, 2005.

[9] J.A. Stevens, K. Thomas, L. Teh, Greenspan et al, "Unintentional fall injuries associated with walkers and canes in older adults treated in U.S. emergency departments", J Am Geriatr Soc. Issue 57, No. 8, pp. 1464–1469, 2009.

[10] D.D. Ely, G.L. Smidt, "Effect of Cane on Variables of Gait for Patients with Hip", Phys. Ther., No. 57, pp. 507-512, 1977.

[11] Majd Alwan et al., "basic Walker-Assisted gait Characteristics Derived from Forces and Moments Exerted on the Walker's Handles: results on normal subjects", Medical Engineering and Physics, No. 29, pp. 380-389, 2007.

[12] Alvaro Muro-de-la-Herran, Begonya Garcia-Zapirain and Amaia Mendez-Zorrilla, " Gait Analysis Methods: An Overview of Wearable and Non-Wearable Systems, Highlighting Clinical Applications", Sensors Review, 14, pp. 3362-3394, 2014.

[13] Joel A. Delisa, Department of Veteran Affairs, "Rehabilitation Reserach and Development Service", Chapter 2, pp. 11-32, 1981.

[14] E.Sardini, M. Serpelloni, M. Lancini, Wireless Instrumented Crutches for Force and Movement Measurements for Gait Monitoring", IEEE Transaction on Instrumentation and Measurement, Vol. 64, No. 12, pp. 3369-3379, Dec. 2015.

[15] S.K. Keadle, E.J. Shirom, P.S. Freedson, I.M. Lee, "Impact of accelerometer data processing decisions on the sample size, wear time and physical activity level of a large cohort study", BMC Public Health, 14:1210, 2014.

[16] I.M. Lee, E.J. Shiroma, " Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges", Br J Sports Med., 48(3), pp. 197-201., Feb. 2014.

[17] J.M. Dias Pereira, Octavian Postolache, Vítor Viegas, Pedro Silva Girão , "A Low Cost Measurement System to Extract Kinematic Parameters from Walker Devices", Instrumentation and Measurement Technology Conference (I2MTC), Vol. 1, pp. 1991-1996, 2015.

[18] Ayudas Dinâmicas, Model AD232. Available at: http://www.ayudasdinamicas.com/caminador-de-incorporacion/ [accessed Oct. 2016].

[19] MDFLY Electronics, Wireless Bluetooth TTL Transceiver Module. Available at: http:// www.mdfly.com [accessed Sept. 2014].

[20] J.M. Dias Pereira, Vítor Viegas, Octavian Postolache, Pedro Silva Girão, "A Smart and Distributed Measurement System to Acquire and Analyze Mechanical Motion Parameters", Metrology and Measurement Systems, Vol. 20, No. 3, pp. 465-478, 2013.

[21] Interlink Electronics, "Force Sensing Resistors: integration guide and evaluation parts catalog", Available at: http://www.interlinkelectronics.com [accessed Sept. 2014].

[22] Texas Instruments, LFx5x JFET Input Operational Amplifiers. Available at: http://www.ti.com/lit/ds/symlink/lf357.pdf [accessed Oct. 2016].

[23] Mettler-Toledo Gmbh, "Mettler Toledo Spider 1S Scales", Switzerland, 1999.

[24] Pulsed Lite LLC, "LIDAR-Lite, Silver Label". Available: https://github.com/PulsedLight3D [accessed Oct. 2016].

[25] Yokogawa Hokushin Electric, YEW Model 3025 A4 X-Y Recorder. Available at: http://www.electro-meters.com/yokogawa/yokogawa-recorders/3025-2/ [accessed Oct. 2016].

[26] Kevin McQuade, M. Finley, A. Oliveira, "Upper Extremity Joint Stresses During Walker-Assisted Ambulation in Post-Surgical Patients", Revista Brasileira de Fisioterapia, Vol. 15, No.4, pp. 332-337, July/Aug. 2011.