A Dataset for the Automatic Assessment of Functional Senior Fitness Tests using Kinect and Physiological Sensors*

Alexandre Bernardino
Institute for Systems and Robotics
Universidade de Lisboa
Lisboa, Portugal
alex@isr.tecnico.ulisboa.pt

Sergi Bermudez
M-ITI
University of Madeira
Lisboa, Portugal
sergi.bermudez.badia@gmail.com

Fátima Baptista
Faculdade de Motricidade Humana
Universidade de Lisboa
Dafundo, Portugal
fbaptista@fmh.ulisboa.pt

Hugo Gamboa
Faculty of Science and Technology
University of Lisbon
Lisbon, Portugal
hgamboa@fct.unl.pt

***Abstract*— This work presents a dataset of functional fitness tests acquired with Kinect v2 and physiological sensors. The dataset contains both young and senior subjects executing a number of fitness tests meeting scientific standards of reliability and validity. The main objective is the ability to assess lower body strength, endurance, gait speed, agility and balance from the data obtained from commercially accessible devices. The dataset can be used to develop algorithms to automate the assessment of fitness levels in low-cost computer based systems for use at home, gymnasiums or care centers.**

Keywords*— *Functional Fitness, Assessment, Direct measures, ICT-solutions, Older Adults

I. INTRODUCTION

Physical activity has been identified as a key determinant associated with longer life and reduced disability [1,2]. Activity can refer to participation in social, economic, cultural, and is also used to assess the capability to perform all activities daily living (ADLs) [3] While physical activity is an essential prerequisite for daily life activities and participation within society, [4] physical inactivity has been found in up to 82% of community dwelling adults aged 75 and older [5].

While activity seems a simple action, it is in reality determined by a complex interplay of multiple determinants [4[. Moreover, (in) activity and sedentary behavior associated with ageing have profound consequences as well as independent predictors for chronic conditions, frailty and disability [6].

Functional status assumes a fundamental key of the objective to prevent the adverse outcomes of inactivity, as it influences both independence and quality of life in older adults [6,10]. Therefore, the preservation of functional status, i.e., the ability to perform ADL, is generally more important than prolongation of life as a public health goal.

In the elderly the functional status is determined by a set of physical attributes, being the most crucial the mobility, muscle strength and balance. It is indeed from mobility and muscle strength that the European Working Group on Sarcopenia in Older People proposes diagnosing sarcopenia [6]. These attributes are also associated with the prediction of falls [7], non-vertebral osteoporotic fracture [9], loss of functional ability and death [9], nutritional deprivation [6], cardiovascular disease [5], among others clinical conditions. The results from the evaluation of these attributes through the traditional protocols are nevertheless interpreted in a dichotomized way (existence or absence of the clinical condition) and there is not a prediction (prognosis) of the risk of functional independence loss with aging.

Recent advances in ICT-solution have made profound changes in people's daily lives. However, the impact of the technologies on healthcare has been limited. Diagnosis and treatment of diseases are still initiated by occurrences of symptoms, and technologies and devices that emphasize on disease prevention and early detection outside hospitals are under-developed [1]. Besides healthcare, mobile devices have not yet been designed to fully benefit people with special needs, such as the elderly population. On the other hand, many new technologies are being researched to promote exercise (mobile apps, video games, fitness trackers, smart watches, wrist bands, etc.), however these have been successful mostly for the young and healthy population [16]. Seniors and patients with motor or cognitive deficits may encounter difficulty in using autonomously these technologies, which require more personalized assistance to configure their exercise programs or simply the exercises are not well suited.

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The AHA project5 is a joint CMU-Portugal initiative for developing novel methods and technologies for the promotion of exercise programs, with particular emphasis on users with special needs, including seniors and users with motor deficits. Beyond difficulties in interacting with technology, these users are very prone to quit exercise programs due to lack of motivation, forgetfulness or appropriate support.

The project proposes the use of a socially assistive robotic platform provided with artificial intelligence, augmented reality and gamification techniques to increase the adherence and maintenance of users in the exercise program.

Loss of interest in the exercise program is not only due to lack of excitement but also to inadequate difficulty and intensity levels of the exercises. These must be carefully chosen according to the current fitness levels of the user, in order to maximize the exercise benefits and keep the user engagement and safety. In this sense, the correct assessment of the users fitness profile is essential for the success of these technologies. The AHA project adopted a set of exercises from state-of-the-art functional fitness tests [17] to be able to measure, at any point in time, the fitness profile of the users. The exercises were chosen based on the portfolio of sensors available in the assistive robot platform (kinect, video cameras, and physiological sensors) and their correlation to the main fitness dimensions of interest: strength, endurance, gait speed, agility and balance [15].

II. SENIOR FITNESS TESTS

Physical fitness is the set of characteristics an individual has related to its ability to perform physical activity. The main dimensions of health related fitness are the cardiorespiratory endurance, balance, muscular strength, muscular endurance and flexibility [17]. The purposes of fitness testing in the AHA project are the collection of baseline and follow up information to evaluate progress in the individual exercise program. Simultaneously, this allows motivating participants by establishing reasonable and attainable goals in the prescribed exercises, as well as maintaining adequate safety levels.

The study presented in this paper targets relatively healthy men and women aged 60-85 years old. The key inclusion criteria is the ability to walk independently, and autonomy to perform normal everyday activities (e.g., household needs, shopping). Exclusion criteria include medical problems preventing exercise (e.g., chest pain at rest or with activity, emergent hospitalization in the last 6 months, history of bone fracture in the absence of major trauma, limited activity due to weight bearing pain or dyspnea), cognitive impairment as assessed by the Mini Mental State Test (MMST) and any significant co-morbidity that could preclude participation (acute illness, progressive neurological disease, stroke, unstable chronic conditions). For this population we have considered tests to assess musculoskeletal, motor and cardiovascular/aerobic fitness, as described in the following sections.

A. *Musculoskeletal Fitness*

Musculoskeletal fitness consists of muscular strength, endurance and flexibility [16]. Muscular strength refers to the muscle ability to exert force. Muscular endurance is the muscle's ability to continue to perform many successive repetitions.

Flexibility represents the ability to move the limbs in extended ranges of motion and impacts on postural stability and balance. Sufficient strength, endurance and flexibility of arms and legs is imperative in retaining proficient functioning in most daily activities, especially with advancing age. We will focus on lower-body strength assessment because of its role in common activities daily living such as stair climbing, maintain balance, getting out of a chair, bathtube or car.

1-30-second Chair Stand Test: The 30-second Chair Stand test attempts to assess lower-body strength by counting the number of full stands from a seated position that can be completed in 30 seconds with arms folded across the chest (see Fig. 1). A number of studies show that chair stand performance has a high correlation with proven laboratory measures such as one repetition maximum leg press, knee extensor and knee flexor strength [17].

Fig. 1. Illustration of the 30-second chair stand test.

B. *Motor Fitness*

Motor fitness assessment is important since it is related to motor abilities that determine susceptibility to falls and the consequent bone fractures and back problems. However, direct measurements of these abilities are difficult to acquire since they consist in complex combinations of neuromuscular, sensory and proprioceptive functions. Fortunately, measures of whole body balance and coordination provide information on aspects of these functions that can be assessed with simple field tests like the 8-foot up-and-go test and the unipedal stance test.

1) 8-foot Up-and-go Test: The purpose if this test is to assess the agility and dynamic balance in tasks that require quick maneuvering such as getting off a bus in time, going to the bathroom or answering the phone. This is achieved by measuring the number of seconds required to get up from a seated position, walk 2.4 meters, turn, and return to the seated position (see Fig. 2). The 8-foot up-and-go-test has been found to be a good discriminator of fallers and non fallers, with scores of 8.5 seconds of longer being and indicator of increasing risk for falling [17].

Fig. 2. Illustration of a trial of the 8-foot Up-and-go Test.

2) Unipedal Stance Test: The purpose of this test is to assess static balance, in particular the ability to use somatosensory cues (body and ground) to maintain upright balance while standing in a reduced base of support and with or without vision. Participants stand barefoot on the limb of their choice, with the other limb raised, near but not touching the ankle of the stance limb, and the arms crossed over the chest (see Fig. 3). Time ended when the subject either: (1) used his arms (i.e., uncrossed arms), (2) used the raised foot (moved it toward or away from the standing limb or touched the floor), (3) moved the weight-bearing foot to maintain his balance (i.e., rotated foot on the ground), (4) a maximum of 45 seconds had elapsed, or (5) opened eyes on eyes closed trials. The score is the amount of time the subject was able to stand in one limb [14].

Fig. 3. Illustration of the correct posture for the Unipedal Stance Test.

C. Aerobic/Cardiorespiratory Fitness

Aerobic or Cardiorespiratory Fitness (CRF) is considered one of the single most important dimensions of overall functional fitness needed for everyday physical demands. The maximal oxygen uptake V O2 max is accepted as the criterion measure of CRF. It is the the product of maximal cardiac output and arterial-venous oxygen difference, being closely related to functional capacity of the heart. Because direct measurement of V O2 max is expensive, a variety of indirect measurements via exercise tests is typically used.

1) 2-minute Step test: The 2-minute step test is an aerobic endurance test suited to time and space restricted environments. It consists in counting the number of full steps completed in 2 minutes, raising each knee to a point midway between the patella (knee-cap) and iliac crest (top hip bone). The score is the number of times the right knee reaches the required height (see Fig. 4) [17].

III. THE DATA ACQUISITION SETUP

A data acquisition setup was assembled with commercially available sensors of 3D depth (Microsoft KinectTMv2) and physiological signals (BiosignalspluxTM), shown in Fig. 5. The Kinect v2 sensor is able to acquire RGB, infrared and depth images of the environment, and compute in real-time (30Hz) the articulated pose of the body skeleton (24 joints) of persons located between 0.5m to 4.5m from the sensor (see Fig. 6). Despite some range and accuracy limitations, the Kinect Sensor has been employed in a multitude of applications in health care with notable potential in making therapy and alert systems financially accessible and medically beneficial to a large population [20]. For our purpose, its field of view of 70x 60 degrees and depth accuracy of about 1cm [19], is in theory accurate enough to compute the considered fitness test metrics.

Fig. 4. Illustration of the 2-minute step test.

The Biosignalsplux is a wearable body sensing platform able to acquire a diversity of physiological signals and transmit them via radio (bluetooth). In this work we have recorded electrocardiogram, respiration rate, blood volume pressure and 3-axes acceleration at the hip. Fig. 7 shows the acquired physiological signals during an exercise trial. This sensing platform has been used successfully in several research and clinical applications [11], [12], [13].

A fisheye camera Vivotek FE8174 was also used to acquire low rate video images that, although not made available for privacy reasons, were used for easier segmentation of the exercises time span. An acquisition platform was assembled containing the all sensing and computational resources required for data recordings and installed at a room with a 3x4m free space area for the exercises. Fig. 8 shows the assembled data acquisition and recording system.

Fig. 5. The main sensors used in this work: the Kinect V2 sensor (top) and the Biosignalsplux.

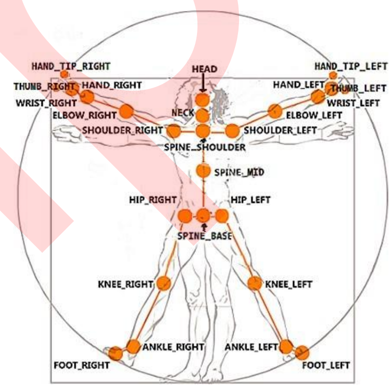

Fig. 6. The skeletal body joints measured by the Kinect V2 sensor.

IV. THE DATASET

We have acquired multiple repetitions of all the above indicated fitness tests (unipedal stance test; 8-feet up- and-go;30 second chair stand test; 2-minute step test) for each subject: 11 young adults (7 females, 4 males) and 10 senior adults (9 female, 1 male), with a mean age of about 61 years old. Acquisitions were performed at the Faculty of Human Kinetics from University of the Lisbon between May and July 2015. Data was stored in a MongoDBTMdatabase and subsequently converted to MatlabTMfiles. The dataset contains the skeleton data recorded at 30Hz and the physiological signals sampled at about 200Hz. All samples are time-stamped with millisecond resolution. Kinect RGB and Fisheye camera data are not released to preserve privacy. Figures 9-12, illustrate the skeleton data acquired during the exercises/tests, namely, unipedal stance test (fig. 9), (8-feet-up and go test (fig. 10), 30 seconds chair stand test (fig. 11) and 2-minutes step test (fig. 12).

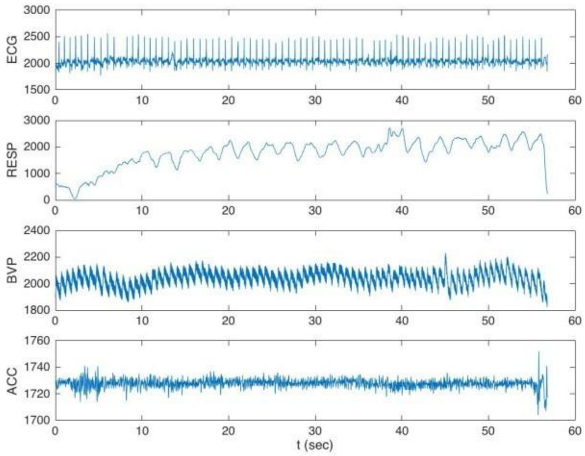

Fig. 7. Signals acquired by the Biosignalsplux during an exercise. ECG = Electrocardiogram, RESP = Respiratory rate, BVP = Blood Volume Pressure, ACC = Acceleration (one of the axes is show).

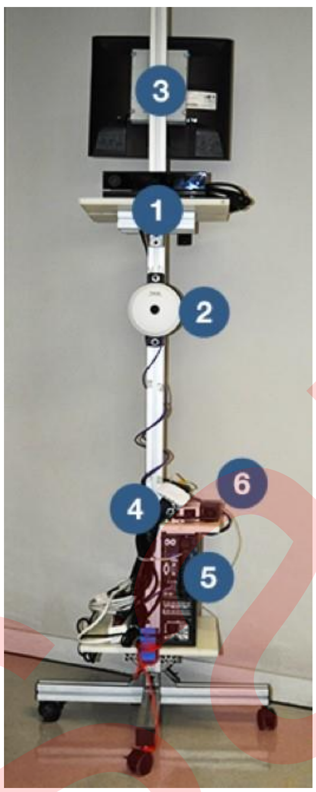

Fig. 8. The data acquisition and recording system. 1 - Kinect sensor, 2 - Fish eye camera, 3 - Computer Screen, 4 - Bluetooth receiver, 5 – PC Computer, 6 - Data Storage Hard Drive.

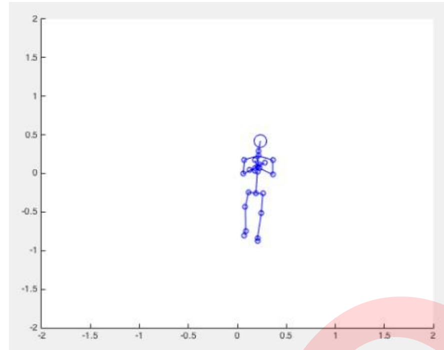

Fig. 9. Sample skeleton acquisition of the unipedal stance test.

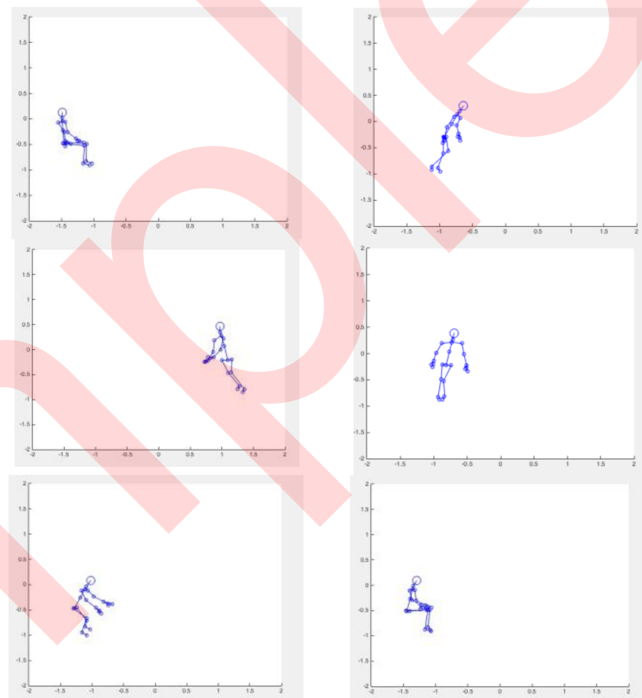

Fig. 10. Sample skeleton acquisitions of the 8-feet up-and-go test.

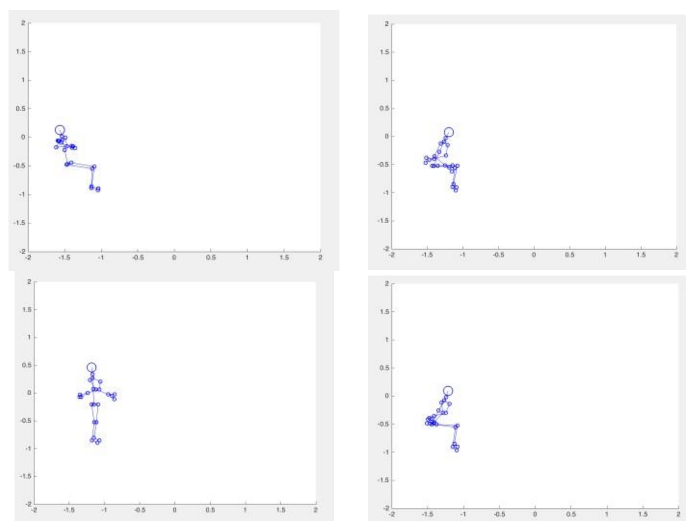

Fig. 11. Sample skeleton acquisitions of the 30-second chair stand test.

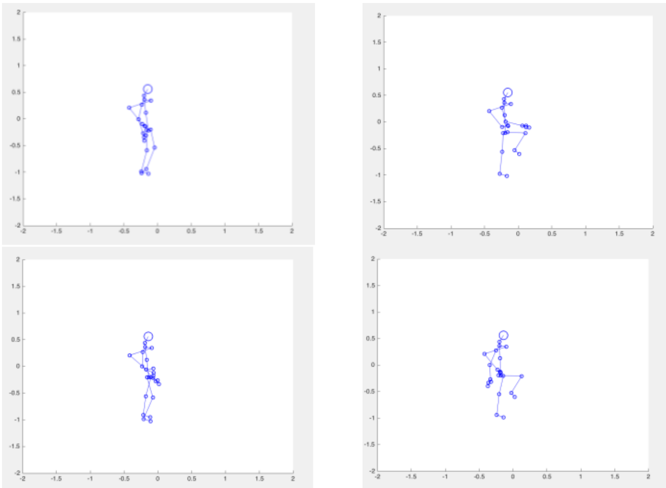

Fig. 12. Sample skeleton acquisitions of the 2-minute step test.

V. CONCLUSIONS

A multimodal dataset containing kinematic and electrophysiological data of 4 important senior fitness tests has been acquired using commercially available hardware. 11 young and 10 senior subjects have participated in the recording sessions and made their data anonymously available for research. The acquired data has sufficient quality to reproduce the scores of the different fitness tests as well as enable further studies with the available signals. Our next steps will consist in annotating specific events in the exercises so temporal correlations can be assessed across the different signal dimensions.

REFERENCES

[1] Yates LBD, L.; Kurth, T.; Buring, J.E.; Gaziano, J.M. Exceptional longevity in men: modifiable factors associated with survival and function to age 90 years. Arch Intern Med. 2008;168:284-90.

[2] Chakravarty EFH, H.B.; Lingala, V.B.; Fries, J.F. Reduced disability and mortality among aging runners: a 21-year longitudinal study. Arch Intern Med. 2008;168:1638-46.

[3] Organization WH. International Classification of Functioning Disability and Health 2015. Available from: http://www.who.int/classifications/icf/en/.

[4] King AC KD. Physical activity for an aging population. Public Health Reviews. 2010;32(2):401-26.

[5] al MEe. Prevalence and correlates of physical inactivity in community-dwelling older adults in Ireland. PLoS One. 2015;10(2):e0118293.

[6] Rothman MD L-SL, Gill TM. Prognostic significance of potentially frailty criteria. J Am Geriatr Soc. 2008;65(12):2211-6.

[7] Fraix M. Role of the musculoskeletal system and the prevention of falls. J Am Osteopath Assoc. 2012 Jan;112(1):17-21.

[8] Cruz-Jentoft et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. Age Ageing. 2010 Jul;39(4):412-23. doi: 10.1093/ageing/afq034. Epub 2010 Apr 13. 2012

[9] Ortega F. et al. Muscular strength in male adolescents and premature death: cohort study of one million participants BMJ 2012;345:e7279 doi: http://dx.doi.org/10.1136/bmj.e7279

[10] Rikli J, Jone J (2012) Development and validation of criterion-reference clinically relevant fitness standards for maintaining physical independence in later years. The Gerontologis,0: 1-13.T. R., Liyanagunawardena, and S. A. Williams, S. A. "Massive open online courses on health and medicine: Review," Journal of Medical Internet Research, vol. 16, no. 8, e191, 2014.

[11] Barandas M, Gamboa H, Fonseca JM, A real time biofeedback system using visual user interface for physical rehabilitation, Procedia Manufacturing 3, 823-828, 2015

[12] Machado IP, Gomes AL, Gamboa H, Paixo V, Costa RM, Human activity data discovery from triaxial accelerometer sensor: Nonsupervised learning sensitivity to feature extraction parametrization, Information Processing & Management Journal, Pergamon 2014

[13] Rebelo D, Amma C, Gamboa H and Schultz T. Human Activity Recognition for an Intelligent Knee Orthosis. In Proc. of the Int'l Conf. on Bio-inspired Systems and Signal Processing (BIOSIGNALS), pp. 368-371, 2013.

[14] Springer BA, Marin R, Cyhan T, Roberts H, Gill NW, Normativevalues for the unipedal stance test with eyes open and closed. J Geriatr. Phys Ther, 30(1):8-15, 2007.

[15] Jones CJ and Rose DJ (Eds), Physical activity instruction of older adults. Champaign, IL: Human Kinetics, Inc. 2005.

[16] Lippincott Williams & Wilkins, ACSMs guidelines for exercise testing and prescription, Wolters Kluwer, Ninth Edition 2014.

[17] Roberta E. Rikli and C. Jessie Jones, Senior Fitness Test Manual, Human Kinetics (2nd Ed.), 2012.

[18] Rose DJ, Lucchese N, Wiersma LD. Development of a Multidimensional Balance Scale for Use With Functionally ndependent Older Adults. Arch Phys Med Rehabil. 2006;87(11): 14781485. doi:10.1016/j.apmr.2006.07.263.

[19] Lachat E, Macher H, Landes T, and Grussenmeyer P. Assessment and Calibration of a RGB-D Camera (Kinect v2 Sensor) Towards a Potential Use for Close-Range 3D Modeling, Remote Sensing. 2015;7:13070-13097.

[20] Webster D and Ozkan Celik, Systematic Review of Kinect Applications in Elderly Care and Stroke Rehabilitation, Journal of Neuroengineering and Rehabilitation, 11:108, 2014.Disease patients," Front. Hum. Neurosci., doi: 10.3389/conf.fnhum.2016.220.00023, 2016.