Revista Iberoamericana de las Ciencias Computacionales e Informática
ISSN: 2007 - 9915

Procedimientos computacionales en la adquisición y captura de datos antropométricos

Computational procedures in the acquisition and capture of anthropometric data

Procedimentos computacionais na aquisição e captura de dados antropométricos

Claudia Ramírez Martínez
Universidad Autónoma de San Luis Potosí, México
claudia.ramirez@uaslp.mx
https://orcid.org/0000-0001-5187-9375

Resumen

El objetivo de la presente investigación fue señalar los procedimientos computacionales empleados para la adquisición, lectura y captura de datos antropométricos relacionados con las siguientes variables: peso, talla, envergadura, diámetro y perímetro de cintura, umbilical y de cadera, índices de masa corporal, índice de masa ósea, porcentaje de agua en el cuerpo, entre otros. Los datos recabados fueron obtenidos a) de forma manual; b) de manera digital y manual, c) a través de tecnología por infrarrojo, y d) en comunicación por *bluetooth*. El grupo de participantes estuvo constituido por 50 mujeres y 50 hombres, cuyas edades oscilaban entre los 19 y los 25 años, pertenecientes al estado de San Luis Potosí. Las mediciones fueron realizadas con *hardware* y *software* comercial en México, de modo que se presentan las ocurrencias por captura de sensores infrarrojos con Kinect. Los datos recabados demuestran que las mediciones realizadas deben ser cuidadosamente atendidas al momento de su captura, pues se evidencia la presencia de ruido por infrarrojo, particularmente en los puntos de extremidades inferiores. Para este estudio se contó con el permiso del Comité de Ética en Salud de la Facultad de Medicina de la Universidad Autónoma de San Luis Potosí y con el apoyo del proyecto SEP-Conacyt CB-2015-257902

Generación de información antropométrica básica en población adulta en el estado de San Luis Potosí. En este estudio no se midieron menores de edad.

Palabras clave: antropometría, captura de información, comunicabilidad, errores, infrarrojo, set, soluciones.

Abstract

The objective of the present investigation was to indicate the computational procedures used for the acquisition, reading and capture of anthropometric data related to the following variables: weight, height, span, diameter and perimeter of waist, umbilical and hip, body mass indexes, Bone mass index, percentage of water in the body, among others. The data collected were obtained a) manually; b) digitally and manually, c) through infrared technology, and d) in bluetooth communication. The group of participants consisted of 50 women and 50 men, whose ages ranged between 19 and 25 years, belonging to the state of San Luis Potosí. The measurements were made with commercial hardware and software in Mexico, so the occurrences are presented by capturing infrared sensors with Kinect. The data collected shows that the measurements made must be carefully taken care of at the time of capture, as the presence of infrared noise is evident, particularly at the points of the lower extremities. For this study, the Health Ethics Committee of the Faculty of Medicine of the Autonomous University of San Luis Potosí and with the support of the project SEP-Conacyt CB-2015-257902 Generated basic anthropometric information in the adult population in the state of San Luis Potosí. In this study, no minors were measured.

Keywords: anthropometry, information capture, communicability, errors, infrared, set, solutions.

Resumo

O objetivo deste estudo foi apontar os procedimentos computacionais utilizados para a aquisição, a leitura e captura de dados antropométricos relacionados com as seguintes variáveis: peso, altura, tamanho, de diâmetro e circunferência da cintura, ancas e umbilicais, índice de massa corporal, Índice de massa óssea, porcentagem de água no corpo, entre outros. Os dados coletados foram obtidos a) manualmente; b) digitalmente e manualmente, c) através da tecnologia de infravermelhos, e d) na comunicação bluetooth. O grupo de participantes consistiu de 50 mulheres e 50 homens, com idades entre 19 e 25 anos, pertencente ao estado de San Luis Potosi. As medidas foram realizadas com o software comercial e hardware no México, para que ocorrências capturar sensor infravermelho com Kinect são apresentados. Os dados recolhidos mostram que as medições devem ser cuidadosamente aberta quando capturado, uma vez que a presença de ruído de infravermelhos é evidente, particularmente nos pontos de extremidades inferiores. Para este estudo contou com a autorização do Comitê de Ética em Saúde da Faculdade de Medicina da Universidade Autônoma de San Luis Potosi e apoiou o projeto SEP-CONACYT CB-2015-257902 geração de dados antropométricos básicos na população adulta o estado de San Luis Potosí. Neste estudo, nenhum menor foi medido.

Palavras-chave: antropometria, captura de informação, comunicabilidade, erros, infravermelho, conjunto, soluções.

Fecha Recepción: Enero 2018 **Fecha Aceptación:** Mayo 2018

Introduction

The computational procedures for the acquisition and capture of anthropometric data can be done through sensors (Fusca, Perego and Andreoni, 2018, Rezzoug, Hansen, Gorce and Isableu, 2018), infrared technology (Shiratori, Park, Sigal, Sheikh and Hodgins, 2011) and applications for communication via bluetooth (Martínez Martínez, Aguilera Cortés, Serratos and Negrete García, 2002), which although they can be read, are not usually communicated for the subsequent treatment of information. In this sense, variants in the capture of movement are an issue frequently addressed in anthropometry (von Marcard, Rosenhahn, Black and Pons-Moll, 2017), although historically the reference positions are static. In fact, the estimations through models have served to question the effectiveness in the capture and in the realization of 3D and predictive models in computer systems (Ionescu, Papava, Olaru and Sminchisescu, 2014), which has been used as support for propose algorithms in the implementation of new hardware (Sigal, Balan and Black, 2010).

Objective

The objective of the present investigation was to indicate the computational procedures used for the acquisition, reading and capture of anthropometric data related to the following variables: weight, height, span, diameter and perimeter of waist, umbilical and hip, body mass indexes, Bone mass index, percentage of water in the body, among others. For this process, we had the permission of the Health Committee of the Faculty of Medicine of the Autonomous University of San Luis Potosí. The data collected were obtained a) manually; b) digitally and manually, c) through infrared technology, and d) in bluetooth communication. The group of participants consisted of 50 women and 50 men, whose ages ranged between 19 and 25 years, belonging to the state of San Luis Potosí. The study was developed with the SEP-Conacyt project of basic sciences. Generation of anthropometric information in the adult population in the state of San Luis Potosí. It is worth noting that this article only focuses on the acquisition, reading and initial capture of the data collected, since the subsequent statistical work involves another treatment of the information.

Method

In this research we worked with the empirical scientific method, which constitutes a valid way to examine certain phenomena that may or may not occur before our senses (Bunge, 1986). Likewise, the R & D methods of computing were implemented (Barchini, 2005), which were applied from the following stages:

1. Installation and calibration of the weighing and measuring equipment.
2. Installation of commercial software and hardware.
3. Tests and adjustments for reading and data acquisition by bluetooth on the Iwellness scale.
4. Tests and adjustments for infrared data acquisition.
5. Organization of electronic files.

The observations were made during two periods (September-December 2017 and April-July 2018) in the area of the basic science project of the Faculty of Habitat of the Autonomous University of San Luis Potosí. Once presented the informed consent and the general data sheet of the participants, they were asked to wear, preferably, short pants and tight shirt. Also, they were asked not to wear shoes or cell phones to avoid interference with the electronic equipment used.

Each person was measured in size and weight twice by the anthropometrist, who was responsible for dictating to his assistant the information collected so that it was recorded in the general data sheet. These figures were provided to the capturist, who emptied them into the Kinect software. The process ended after the person was measured on the Iwellness scale. It is important to mention that the data recording formats of the anthropometric procedures have a legal basis, which is not usually known in the different areas of health.

For the measurements of size, a manual stadiometer brand Seca-217 was used, which has a range of between 20 cm and 205 cm. Likewise, three Medidata brand scales were used: the first had an extensible manual height rod and a digital screen reader; the second (model ms 200/400) had an infrared stadiometer and a digital screen reader; In this scale, some data such as age and gender can be entered manually, which generates the body mass index (BMI) by electrical impedance. In this it is not possible to output data, because it has a marked hardware, although without physical access (that is, in this scale model the information is limited to reading the screen). The third scale was WCS 400/800 model for wheelchair users, with a weight limit of 400 kg and wireless digital screen with data output possibilities for serial port printing RS232 interface. It is worth noting that in no case was any software provided. Table 1 shows the minimum divisions and ranges of each scale.

Tabla 1. Especificaciones de los equipos utilizados en el estudio

Descripción del equipo	**Marca**	**Modelo**	**Alcance de medición**	**División mínima**
Báscula con tallímetro infrarrojo	Medidata Torrey	ms 200/400	Máx. 200 kg / 400 lb Mín. 1 kg	d = 0.05 kg
Báscula con lector digital	Medidata	HWI 200/400	Máx. 200 kg / 400 lb	d = 0.05 kg / 0.1 lb
Báscula para silla de ruedas WCS	Medidata	WCS-400/800	Máx. 400 kg / 800 lb	d = 0.2 kg / 0.5 lb
Báscula *Bluetooth*	Iwellness benêtre	CPMX335BLE	Máx. 180 kg Mín. 5 kg	No especificada
Estadiómetro	Seca	217	20-205 cm / 8-81¨	d = 1 mm / 1/8”

Fuente: Elaboración propia

The scale used Iwellness is marketed with the impedance reading of eight different data: body weight, body fat, body water percentage, muscle mass, body mass index, basal metabolic rate, bone mass and visceral fat. Commercially, this model includes software for cell phones and tablets with Bluetooth 4.0 and higher connectivity. The Iwellness application, although included for free and advertised with NOM certification, involves the communication of data via email or text messages; contradictorily, once the data of sex, age and height are entered manually in the software, only the weight and the body mass index are communicated, and not the indexes that can be read on the cell phone or tablet screen. This software can also be manipulated by ten users.

Revista Iberoamericana de las Ciencias Computacionales e Informática
ISSN: 2007 - 9915

On the other hand, a Kinect V2 Xbox-one sensor was connected to a PC computer to capture infrared anthropometric points, which was located on a tripod at 0.8 m height and at a distance of 2.1 m from each person (in the In the case of people over 1.85 m tall, the sensor was placed 2.5 m away). The Kinectomatics software is used to capture 16 anthropometric points once the name, size, weight, sex and age data have been entered manually. The weight and height data were observed with the naked eye and were given to a person who served as a pointer; then the capturist emptied them into the Kinectomatics program for subsequent calculations. The output result was transferred to the PC by creating a .csv file. In figure 1 the armed set for the capture in Kinect is shown.

Figura 1. Contexto del set con el sensor IR una vez instalado y listo para emplearse

Fuente: Elaboración propia

Results

Next, the results are presented according to the proposed order:

1. Installation and calibration of weighing equipment and size measurement

The equipment was acquired in Mexico and was located in a space destined for this project, specifically in the Faculty of Habitat of the Autonomous University of San Luis Potosí. The calibration was carried out in the said faculty and was certified in November 2017 by Advanced Technology Center (CIATEQ), San Luis Potosí headquarters. Equipment calibration is a procedure that provides data to calculate uncertainty and possible errors; This implies a detailed knowledge on the repeatability and reproducibility of the studies carried out not only in health areas, but also in other specialties.

Regarding the national laboratory, it was considered as a requirement of the project before the National Council of Science and Technology (Conacyt). The values obtained were in proof of indication error, nominal load, measurement error rise and measurement uncertainty. In the statistical treatment after reading the data, these values will be related to the estimates for statistical errors in the study.

2. Installation of commercial software and hardware

In the case of scales with digital screens, the search for communication of data obtained between the scale and the PC required exploration and consultation with various specialists. However, it was not possible to establish a communication, given that commercial software was not available with a certainty of operation in the purchased models. In fact, it was concluded that it was necessary to make a particular contract with a programmer or software company for the specific data generated by these scales.

Due to this, we proceeded to look for some software online, so that it was specified that there are community supports of software in the network. Even so, and given that the objective was to obtain anthropometric data, and not to program, the results were treated visually (that is, the anthropometrist dictated them to a prompter, who wrote them down manually in the data template). Then the Kinect capturist used this data as a complementary part of the Kinectomatics program, with the possibility of error by writing or reading in the format.

On the other hand, it should be noted that among the three Medidata scales there are differences related to the possibilities of communicable and non-communicable data. For example, in the first scale in terms of digital reading of weight, height and calculation of the body mass index. Also, the second scale only with the possibility of communication of the weight with a PC or printer by serial port, since it has a hand height meter. Finally, the scale for people in wheelchairs offers reading on the digital screen and communication for bluetooth printing, but does not allow capture on PC with commercial programs such as Microsoft Excel, Numbers, etc. These particularities in the scales of the same brand represent an obstacle to consider the direct use in PC and, consequently, to avoid errors by dictation, writing or capture of the information.

3. Tests and settings for reading and acquisition by bluetooth

In the Iwellness scale, the data is obtained by the impedance method towards the digital screen in relation to the weight. The index calculations are provided in the brand software in portability for cell phone and tablet. Although the data were observed, the output was limited to weight and body mass index, without counting the output of the other indexes obtained on the screen. The biggest problem with this scale was in the communication by bluetooth. Specifically, the program did not respond on the cell phone or on the tablet. Another drawback was the lack of memory capacity required in these devices. In this type of scale, in addition, an error was observed that arose as the weights increased. All these obstacles were presented continuously, so it was decided not to take it into account for the next step of statistical treatment.

4. Tests and adjustments for data acquisition by IR Kinect Xbox-one

Among the commercial programs for the capture of human and anthropometric figures, a variety of possibilities were found (open access or private, with different functions, etc.). In this case, the Kinectomatics software was used. The Kinect V2 infrared sensor was placed on a tripod at a height of 0.89 m and facing the person in the wingspan position. Likewise, vinyl marks were placed to locate the sensor 2.1 m away and 2.8 m in the case of people over 1.9 m tall. Also, another mark was added at a distance of 40 cm from the wall to indicate the place where the person should stand.

This sensor allowed a tracking or tracking through the selection of body parts, either by infrared (as a complete photograph) or by bone ends and joints (by x, y, z coordinates for each end point or joint, which can store in a .csv file). Table 2 shows two series of points obtained in x, y, z of the right and left lower extremity, respectively. The first ones have to do with hip, knee, ankle and foot on the right side, respectively, while the second ones show the values of the same extremities, but on the left side.

Tabla 2. Ejemplo del registro de una captura con Kinect

P1_HipRight_X	P1_HipRight_Y	P1_HipRight_Z	P1_KneeRight_X	P1_KneeRight_Y	P1_KneeRight_Z	P1_AnkleRight_X	P1_AnkleRight_Y	P1_AnkleRight_Z	P1_FootRight_X	P1_FootRight_Y	P1_FootRight_Z
-219.8408	-286.5261	2722.044	-315.4078	-588.6768	2602.442	-333.74	-863.1378	2627.576	-297.0755	-933.6657	2672.945

P1_HipLeft_X	P1_HipLeft_Y	P1_HipLeft_Z	P1_KneeLeft_X	P1_KneeLeft_Y	P1_KneeLeft_Z	P1_AnkleLeft_X	P1_AnkleLeft_Y	P1_AnkleLeft_Z	P1_FootLeft_X	P1_FootLeft_Y	P1_FootLeft_Z
-799.189	-296.9508	2765.16	-816.9654	-611.6378	2783.751	-842.9337	-915.1961	2753.929	-811.2552	-987.8072	2658.223

Fuente: Elaboración propia

With this procedure, it is possible to generate the human figure on its sagittal axis, which allows separating the right and left sides, or both, on the horizontal plane, separating upper and lower extremities or both. This, in addition, offers the possibility of temporary capture in seconds and fractions of seconds. In the case of this study, 16 tests were performed in 30 seconds, 20 seconds, 15 seconds and 10 seconds (right side, left side and both, upper, lower and both extremities).

Among the data prior to the capture or tracking that should be entered in the program for each person we find the sex, age (in years), weight (in kilograms) and height (in meters). The registered frequency of the infrared is recorded in each reading and a data row x, y, z is generated for every fractional second. Figure 2 shows a screenshot obtained with the Kinectomatics software. For confidentiality, the information in the Condition line (name of the person) has been omitted.

Reci
Revista Iberoamericana de las Ciencias Computacionales e Informática
ISSN: 2007 - 9915

Figura 2. Pantalla de un archivo .csv con los datos generados

	A	B	C	D	E	F
1	Kinectomatics					
2						
3	Date	12/07/2018	[redacted]	h	JessicaCONALEP	
4	Frequency (H	12.74		Weight	61.06	
5	Total Sample	191		Height	1.587	
6	Units	Millimeter		Age	19	
7	GCS Transfor	Off		Sex	F	
8						
9						
10	Time (s)	P1_Head_X	P1_Head_Y	P1_Head_Z	P1_Neck_X	P1_Neck_Y
11	0.049	24.69226	603.6735	2237.728	20.04509	470.3096
12	0.148	24.80967	603.5297	2237.249	20.07458	470.2213
13	0.246	25.03345	603.4035	2236.828	20.03934	470.227

Fuente: Elaboración propia

A frequent problem, although solvable, was the freezing of the program. For this, once the captures are generated, all the reading files of each session can be kept in the same folder and separated after finishing the capture, not as the software interface is presented (where it would be possible to change the folder for each person).

Another mishap found, but equally solvable, had to do with the storage of a capture without the acquisition of numerical data x, y, z. In this case the generated .csv files were considered invalid, and the captures of the people were repeated until a valid registration was obtained. Table 3 shows an example of points of the head once the capture time has been traveled, but with an invalid reading. In fact, although the program was executed in second partitions (Time column), the results obtained were of text type (NaN), and not numeric as expected. In this case, the null registry was considered.

Tabla 3. Muestra de un registro nulo

Time (s)	P1_Head_X	P1_Head_Y	P1_Head_Z	P1_Neck_X
0.088	NaN	NaN	NaN	NaN
0.224	NaN	NaN	NaN	NaN
0.348	NaN	NaN	NaN	NaN
0.433	NaN	NaN	NaN	NaN
0.53	NaN	NaN	NaN	NaN
0.612	NaN	NaN	NaN	NaN
0.691	NaN	NaN	NaN	NaN

Fuente: Elaboración propia

Reci Revista Iberoamericana de las Ciencias Computacionales e Informática
ISSN: 2007 - 9915

Another unforeseen factor in the capture had to do with the noise generated by reflections on the floor. In this case it was observed that columns of the right side were added with the points identified as COM_X, COM_Y, COM_Z for each element produced by noise. Table 4 shows the example of a record of the lower right extremity with a noise point at x, y, z.

Tabla 4. Ejemplo de un registro de ruido

P1_Hip Right_X	P1_Hip Right_Y	P1_Hip Right_Z	P1_Knee Right_X	P1_Knee Right_Y	P1_Knee Right_Z	P1_Ankle Right_X	P1_Ankle Right_Y	P1_Ankle Right_Z	P1_FootRight_X	P1_FootRight_Y	P1_FootRight_Z	P1_COM_X	P1_COM_Y	P1_COM_Z
273.6322	-4.580303	2224.353	320.5666	-346.9763	2256.158	360.1778	-696.0998	2306.076	351.1965	-719.2699	2186.363	205.0459	146.2044	2261.058
273.9265	-4.654973	2224.526	320.8963	-346.9252	2256.124	360.3249	-696.2335	2306.125	373.2952	-757.4719	2249.265	205.3418	145.6076	2261.837

Fuente: Elaboración propia

To correct this variable, a carpet of 1.10 m x 2.0 m, gray, anti-reflective and of commercial use in sound and automotive equipment was implemented. Likewise, a bicolour vinyl tape usually used as a precautionary signal was used.

On the other hand, it is worth mentioning a phenomenon observed constantly in the position of span, specifically related to the separation of the feet, since the standing posture is often confused with the maximum extension of arms in horizontal with the posture of span (vitrubian) , which must be done also including a certain opening between legs, and not with the legs together. In this case, slight jumps between the points detected on the screen were perceived in the course of the scan reading time. As the superpositions of points x, y, z are not feasible in reality, the person was asked for a leg distance between 15 cm and 20 cm, without reaching a maximum opening.

5. Organization of electronic files

Once the capture was done both manually and by Kinect, at least three pdf files were generated for each person studied: one with their informed consent, another with the manual data sheet, and a third with the data obtained through the Kinect. The files were disaggregated by sex for further treatment with R and R Studio.

It was also decided to keep the manual form, since the weights collected in these three Medidata scales were quite accurate, according to the calibration performed by CIATEQ. Given the inaccuracy of the weight with the Iwellness scale, the indices obtained with the software were put in doubt for its use. By involving the weight data in all the internal calculations of the Iwellness scale, a series of non-repeatable data was produced, reason why its use was ruled out. That is, although the intention of some softwares lies in the possibility of reaching a direct reading, the size of the error in weights greater than 60 kg became higher once weights compared to those achieved in the same masses with the Medidata scales. . It is important to know that repeatability is a key factor in the quality of current studies in which reading and data capture are directly related to obtaining images (Pasko y Sutkowski, 2016).

Conclusion

Technology offers multiple opportunities to different areas of knowledge and, in this particular case, to anthropometry, although it should also be emphasized that in many cases this also causes new challenges to arise, which can only be detected through careful observation, repetition, correction of errors and testing of new solutions.

In this specific case, therefore, it can be affirmed that the portability of the data of the anthropometric equipment, both in the stadiometer and in the scales, do not seem to be consistent in the equipment tested. Likewise, direct communication to PC implies specialized knowledge, which can hardly be solved without the intervention of a systems professional.

On the other hand, regarding the classic manual techniques of anthropometry, it is worth mentioning that it has been preferred to repeat each measurement twice in order to reduce errors by obtaining, reading and capturing data. Likewise, it must be said that although there is the possibility of reducing those defects by implementing an automated process, it still has some weaknesses that should be noted, which may arise due to a lack of communication between different areas and specialized studies. (in this case, anthropometrists, software designers and anthropometric teams with the possibility of data communication).

For this, it is necessary to emphasize that the acquisition by infrared with Kinect is a relatively cheap and viable possibility for a large part of the population. Even so, the data provided does not present a greater treatment, so that the points obtained can be worked on confidently, but this requires a subsequent statistical treatment. Indeed, the approach to the various observations made with the Kinect allows us to point out that this team has a series of irregular situations that although in this study could be solved, they require a greater precision in the light and contrast variables of the context where Measure

Regarding infrared photographic technology, it can be said that it is still expensive in different tracking equipment for human figures. Although 3D scanners can be used in this type of studies, the location of anthropometric points in the joints is still in scarce possibilities to be obtained from 3D files. Therefore, the use of sensors such as Kinect and low-cost software has become a viable resource, especially in countries such as Mexico, where educational and research funding is restricted.

Finally, supposing that the capture of data represents an irrelevant step is an error, since the process is accompanied by a series of observations that can be corrected. In fact, the iterative procedure described in this article for the capture of anthropometric information implied different stages that had to be planned and adjusted to the objectives, which were reviewed in detail, since they constitute an aspect of great importance for the majority of anthropometric calculations.

References

Barchini, G. E. (2005). Métodos "I+D" de la informática. *Revista de Informática Educativa y Medios Audiovisuales*, *2*(5), 16-24.

Bunge, M. (1986). *La ciencia, su método y su filosofía*. Ediciones Quinto Sol.

Fusca, M., Perego, P. and Andreoni, G. (2018). Method for Wearable Kinematic Gait Analysis Using a Harmonic Oscillator Applied to the Center of Mass. *Journal of Sensors*. Doi: https://doi.org/10.1155/2018/4548396.

Ionescu, C., Papava, D., Olaru, V. and Sminchisescu, C. (2014). Human 3.6M: Large Scale Datasets and Predictive Methods for 3D Human Sensing in Natural Environments. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *36*(7), 1325-1339. Doi: https://doi.org/10.1109/TPAMI.2013.248.

Martínez Martínez, R., Aguilera Cortés, A., Serratos, J. N. y Negrete García, M. C. (2002). Base de datos antropométricos y maniquí paremetrizado. Herramientas para diseño con criterios ergonómicos. *Acta Universitaria*, *12*(2).

Pasko, S. and Sutkowski, M. (2016). Anthropometric measurement based on structure from motion imaging technique. *Devices and Methods of Measurements*, *7*(3), 305-311.

Rezzoug, N., Hansen, C., Gorce, P. and Isableu, B. (2018). Contribution of interaction torques during dart throwing: Differences between novices and experts. *Human Movement Science*, *57*, 258-266. Doi: https://doi.org/10.1016/j.humov.2017.09.004.

Shiratori, T., Park, H. S., Sigal, L., Sheikh, Y. and Hodgins, J. K. (2011). Motion Capture from Body-Mounted Cameras. *ACM Transactions on Graphics*, *30*(4). Doi: https://doi.org/10.1145/1964921.1964926.

Sigal, L., Balan, A. O. and Black, M. J. (2010). HumanEva: Synchronized Video and Motion Capture Dataset and Baseline Algorithm for Evaluation of Articulated Human Motion. *International Journal of Computer Vision*, *87*(4), 4-27. Doi: https://doi.org/10.1007/s11263-009-0273-6.

Von Marcard, T., Rosenhahn, B., Black, M. J. and Pons-Moll, G. (2017). Sparse Inertial Poser: Automatic 3D Human Pose Estimation from Sparse IMUs. *Computer Graphics Forum*, *36*(2), 349-360. Doi: https://doi.org/10.1111/cgf.13131.