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# MOTION CAPTURE (MoCAP) AND 3D COMPUTER DESIGN FOR ERGONOMICS NEEDS

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**Abstract** 3D digitalization is increasingly used nowadays. Initially 3D software was focused mainly on internal system consumption, and today trends have strengthened the interaction with other systems and new file formats. Through complex conventional techniques, a way was sought to improve the possibilities for 3D modeling of anatomical people in accordance with the anthropometric features. With the development of modern design technologies, the correlation between virtual and real 3D space has become closely related to the entry of 3D scanners, 3D printers and other additive technologies. In the field of ergonomics, there is an opportunity to integrate Motion Capture (MoCAP) technology to 3D computer design to create simulated models of work processes in a virtual environment, in order to study the influence of participants in the human-environment-machine system.

**Keywords:** 3D; MoCAP; Open Source; ergonomics; human factors.

## 1. INTRODUCTION

When we talk about MoCap, we associate it with digitalization. It, in turn, interacts with all in one way or another suitable variants of 3D applicable software ensuring the implementation of the task or project being worked on. MoCap is used to create digital duplicates [1] and is successfully used in [2]:

- Ergonomics. Analysis and optimization aimed at improving ergonomic features.

- Biomechanical Analysis. For example, in athletes, the movements are analyzed in order to develop a training methodology tailored to individual training.

- Animation. For example, in the computer game and 3D film industry. Data on the movements of the actors or objects are recorded and transferred to the virtual environment. This gives the characters realism.

- Interactive presentations. Real-time motion capture and character assignment to create impressive interactive show programs.

- Other. Tailored to the application.

This report aims to summarize the current possibilities for interaction between MoCap and 3D digital design, focusing on the application in ergonomics and human factors. It will also give a greater insight into the fruitful implementation of MoCap and expand knowledge about this technology [3-9]. The

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emphasis is mainly on open source systems and freely available platforms, which allows a wider range of users to work actively at a high level.

This study is part of series of developments needed to build a database of three-dimensional digital models for ergonomic needs of the Bulgarian Association of Ergonomics and Human Factors (BAEHF) [10] within 34-Summer University on Ergonomics / ERGONÓMIAI NYÁRI EGYETEM [11-13].

## 2. METHODOLOGY

Serious technical training is required to create quality simulations in a virtual environment for needs in ergonomics. It includes the presence of sensing equipment with sensors if this technological path is selected or application only on digital platforms that have a database with recorded movements. A good option is to optimize an appropriate methodology allowing the interaction of modern technical means collaborating with 3D software. This requires serious knowledge of the structure of three-dimensional geometry, anatomical features of people, skills to create musculoskeletal movements and simulations. Using the correct file formats is imperative. Important file formats are shown in Table 1. An optimized methodology for interaction between MoCAP and 3D software for needs in ergonomics is shown in Figure. 1.

**Table 1. Important file formats.**

| Full name | File format |
|---|---|
| Biovision Hierarchy / Motion Capture | *.bvh |
| Collada | *.dae |
| Filmbox | *.fbx |
| Stereolithography | *.stl |
| Wavefront | *.obj |

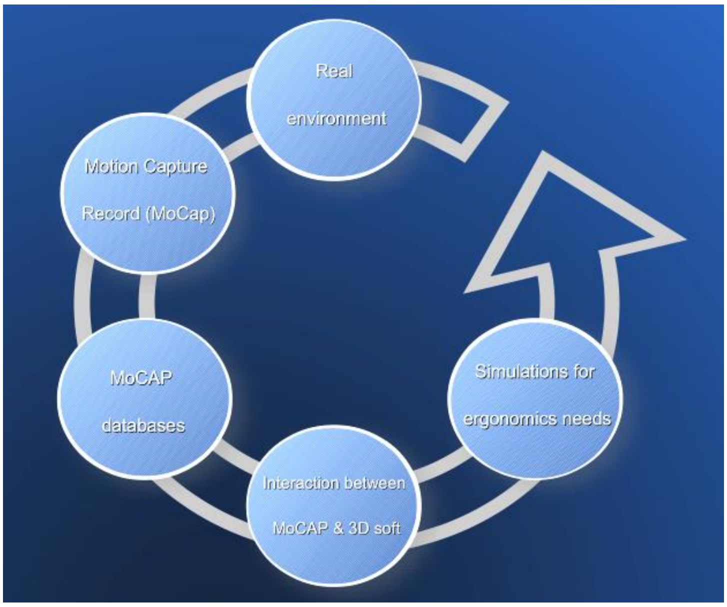


**Figure 1. Methodology for interaction between MoCAP and 3D software for needs in ergonomics.**

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## 3. APPLICATION OF MOCAP AND 3D COMPUTER DESIGN FOR ERGONOMICS NEEDS

Nowadays, there are a number of specialized ergonomic software that are developed on the basis of conventional 3D modeling in a computer environment and / or by applying MoCAP technology.

### 3.1. MoCAP Technology & Specialized Ergonomic Software

Leading specialized ergonomic software is:

- Siemens Tecnomatix software's Motion Capture Toolkit (Figype 2) [14].

**Figure 2. Siemens Tecnomatix software's Motion Capture Toolkit [14].**

The Tecnomatix Motion Capture Toolkit software makes it possible to generate precise and correct movements through which a real-time visualization of human activities is created. This technology optimizes and supports the visual inspection of production processes and product design. By connecting motion capture technology with human modeling, it interacts directly with its virtual environment. This significantly improves design development. The technology includes systems for tracking the whole body, including gloves for tracking complex movements of the hands and fingers.

- Xsens [15] & ViveLab [16] motion capture (Fig. 3).

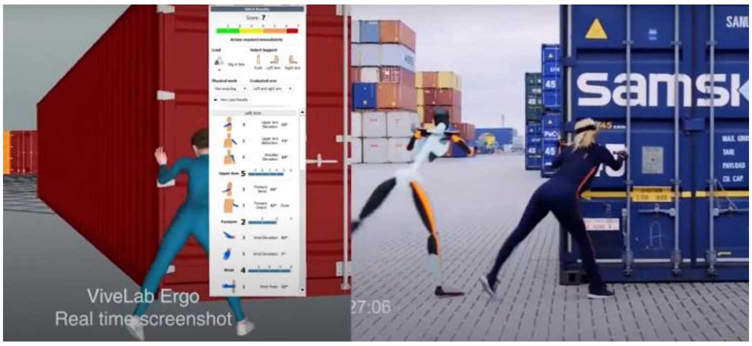


**Figure 3. Xsens [15] & ViveLab [16] motion capture.**

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The Xsens and ViveLab have combined their concepts to create digital duplicates of real characters. Xsens is applied to character animation, including several levels of hardware, software, and cloud processing options. ViveLab Ergo software helps to create the right working conditions and processes for people working in the field of safety and engineering. It performs ergonomic analyzes and defines precise options and parameters for measuring risk through tests. A video presentation can be seen at the video source [17].

### 3.1.1. MoCAP Technology & Conventional 3D Software

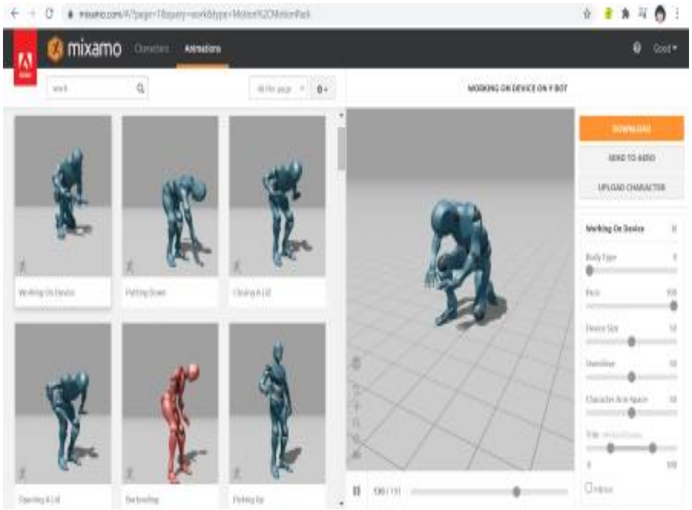
This symbiosis includes the mutual integration between already recorded (digitized) movements of characters (working, ordinary and dynamic motor, etc.) in software supporting and storing a database with MoCAP digital simulation models, which are pre-stored. They can be imported into conventional 3D software, where animated processes can be further developed in a digital environment including environment and objects as intended. It is also possible to first create 3D virtual human characters (with or without armature), and export them to software such as Adobe Mixamo [18] and / or Rokoko Studio [19] (Figures 4 (a) and (b)). There they are driven and re-imported into a suitable 3D environment to continue the simulations, where the workflow ends. Leading 3D conventional polygonal-mesh software are:

- Blender 3D [20],

- Cinema 4D [21],

- Autodesk 3DS Max [22],

- Autodesk Maya [23].





*(a)* *(b)*

**Figure 4. Platforms with MoCap database: (a) Adobe Mixamo [18] and (b) Rokoko Studio [19].**

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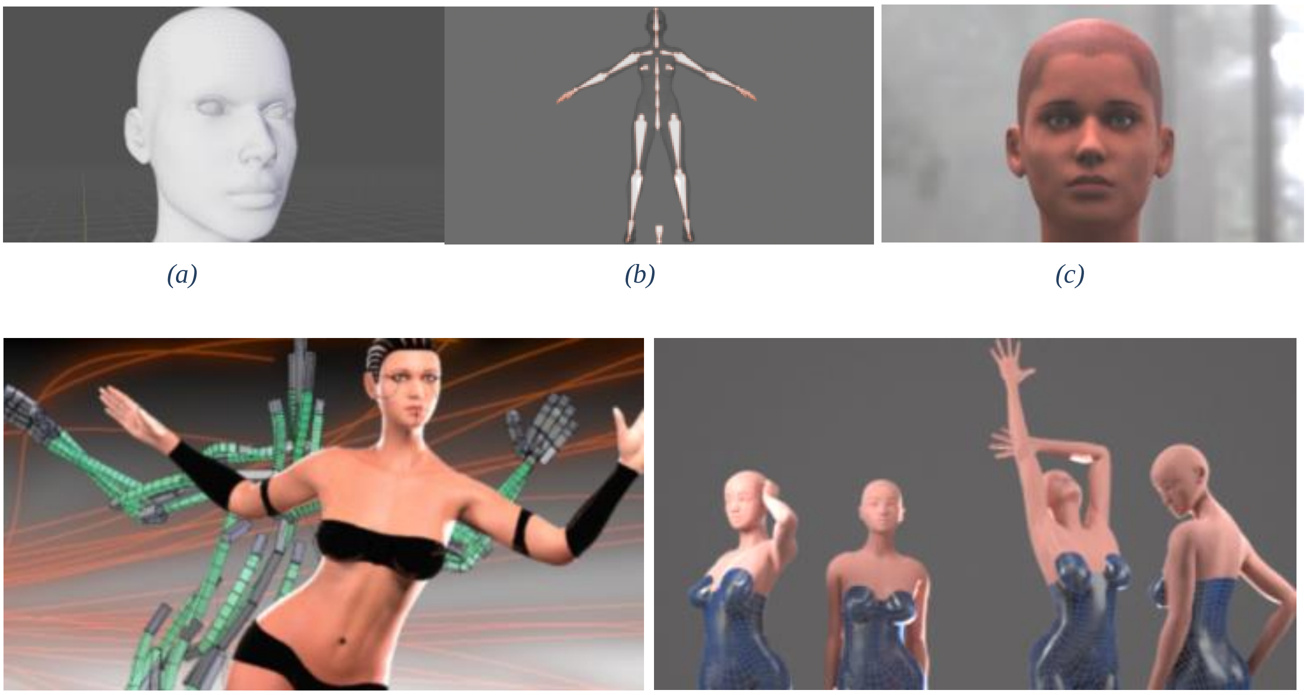
### 3.1.2. Open Source 3D software & Add-ons for creating Human Characters

To create anatomical human characters, the best open source 3D resources are Blender 3D with the accompanying Addon-MB-LAB and MakeHuman software [24]. Blender 3D open source software allows for conventional (manual) construction of people, as well as the construction of a moving skeleton type rigging needed for propulsion and animation. Adding to this the resources of MB-Lab the ability to obtain maximum realism in terms of both three-dimensional geometry and drive is maximized. MB-Lab provides [25, 26]:

- Professional topology;
- Library with anthropological phenotypes;
- Standard skeletal structures;
- Morphing parameters;
- Body measurement system;
- Facial expressions;
- Animated Characters
- Other.

Some of the main features of MB-Lab add-on are shown in Figures 5 (a-e).



*(a)* *(b)* *(c)*

*(d)* *(e)*

**Figure 5. ManuelBastioniLAB (MB-LAB) Open Source Character Creation MB-Lab is a Blender addon that creates human characters [25, 26]: (a) professional topology; (b) skeletal structure / armature; (c) morphing parameters; (d) body measure System; (e) anthropological phenotypes library.**

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### 3.2. Open Source Software for Rigging

For educational purposes, an exemplary model of a conventionally driven model of human character has been developed, which is shown in Figure 6. The software Blender + MB-Lab addon is used as a basis, as the armature is built manually (by hand). To perform movement (rigging) and animation, it is necessary to define key positions and time for each movement. The collected result generates an overall dynamic human character.

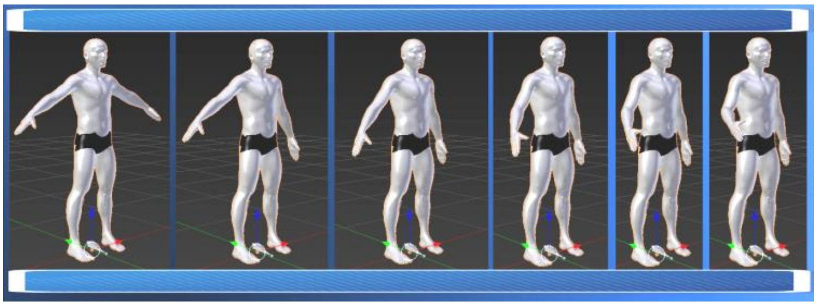
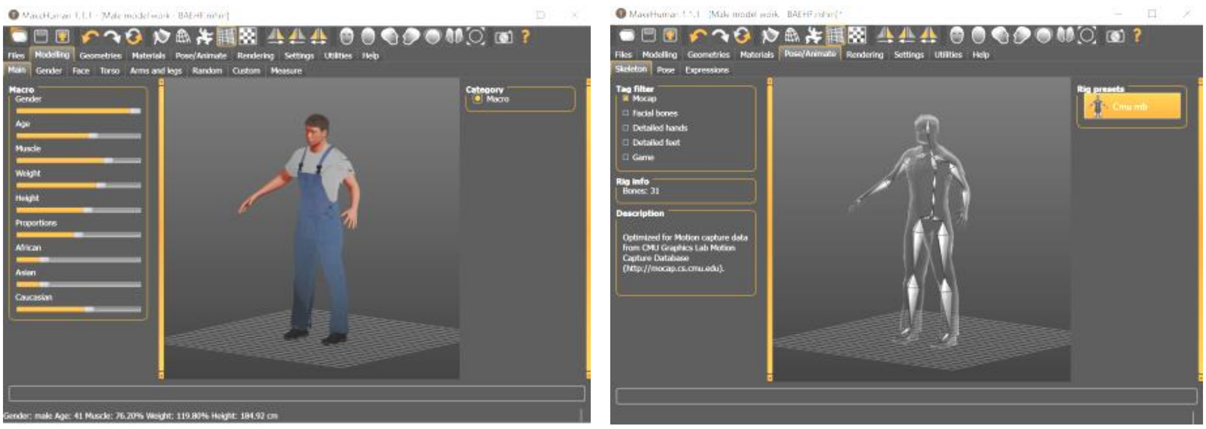


**Figure 6. Blender + MB-Lab: conventional human rigging [27].**

## 4. TECHNICAL REALIZATION

To create 3D-driven human characters for ergonomic needs using open source software and MoCAP database, it is necessary to follow the methodology. The required anatomical parameters of the character are defined, which includes gender, age, muscles, height, weight and other features. All necessary attributes in respect of clothing, footwear and other accessories if required. By assignment it is necessary to develop a character of a working man with the following physical parameters: Age: 41, Muscle: 76.20%, Weight: 119.80%, Height: 184.92 cm. The 3D model is shown in Figure 7 (a). After the model is made parametrically, the movable armature based on MoCAP is constructed to it (Figure 7 (b)). Then it is exported in a suitable file format (*.fbx) for further interaction with the other three-dimensional platforms for realization of simulation actions.



*(a)* *(b)*

**Figure 7. 3D developed model: (a) 3D worker physical parameters: Age: 41, Muscle: 76.20%, Weight: 119.80%, Height: 184.92 cm.; (b) Adding Motion Capture data from CMU Graphics Lab Motion Capture Database direct in MakeHuman environment [28]: http://mocap.cs.cmu.edu/**

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It is recommended to check the created three-dimensional network in a conventional three-dimensional program, where the strength and quality of the network are considered in detail. The specific developed model contains: Vertices: 17,232; Faces: 16,663 (Figure 8).

**Figure 8. Interface of Blender software. Imported from MakeHuman 3D worker model.**

For ergonomic needs, the fully functional 3D model of a male worker is transferred to the Adobe Mixamo platform, where the necessary actions are applied for recorded movements of work processes. Figure 9 shows selected frames from the moving working model: 82, 97, 129, 157 and 234.

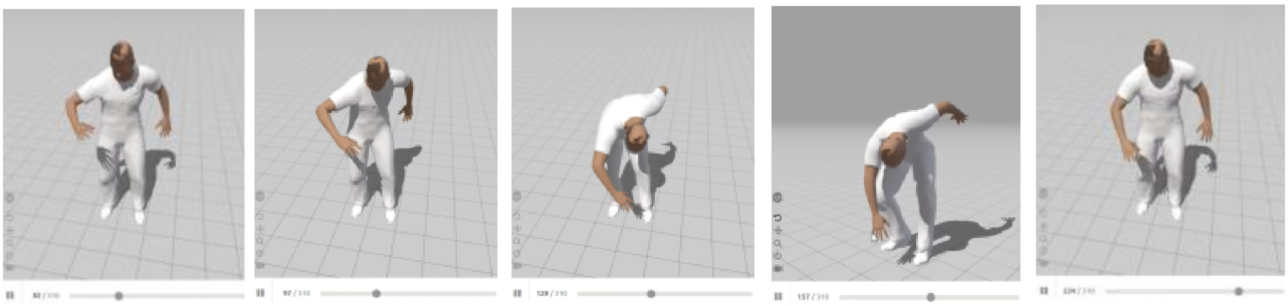

**Figure 9. Interface of Blender software. Imported from MakeHuman 3D worker model.**

Video presentations of completed versions of a digital dynamic model of human character performing certain work processes are available at the following links:

- Push Start
  https://www.youtube.com/watch?v=Zu4rtgn27Hc
- Putting down
  https://www.youtube.com/watch?v=i9QK4JXiufY
- Bartending
  https://www.youtube.com/watch?v=0CRVhMNj2E8

Real-time data of the developed 3D models are available on the Internet platform p3d.in, (Figure

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10).

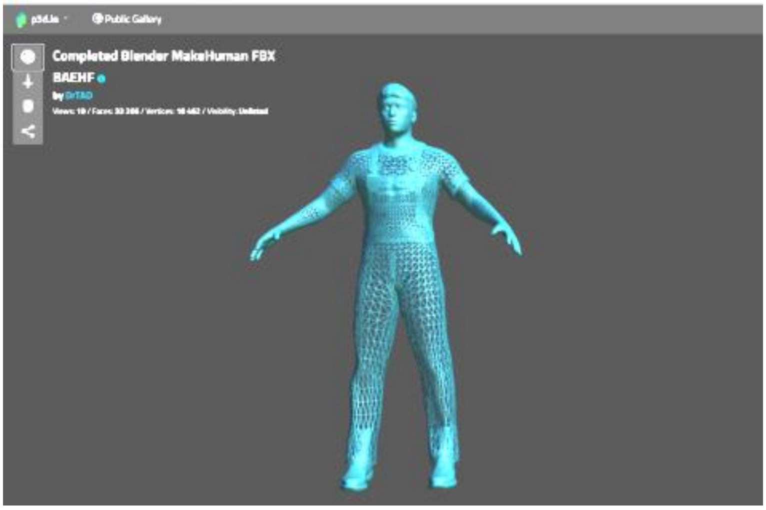


**Figure 10. Real-time presentation of the 3D worker model and mesh view (X-Rey + Wireframe; other): https://p3d.in/P6B87/wire.**

The results of the development of the 3D model by assignment show a quality and very well constructed mesh. This example serves to build a digital library of three-dimensional models that are integrated into the work environment and ergonomic research is performed.

## 5. CONCLUSION

This report presents in details the relationship between MoCAP, specialized file formats and the necessary 3D software to create quality 3D models of human characters. They are used to perform simulations in a virtual environment for needs in ergonomics in order to optimize the behavior of people in a working static and/or dynamic environment. A three-dimensional model of a worker built according to all anatomical requirements has been developed. The model is assigned with the necessary drive skeleton for reinforcement of the muscular system. The model has been successfully transferred to the appropriate animation file formats and is available in real time to receive details. The experience gained in the research is appropriate and fully applicable for the creation of a database of three-dimensional models, which in one concept will ensure the creation of quality simulated ergonomic research.

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## References

[1] Siemens, 2021, Comprehensive digital twin: a multifunctional solution for machine building, https://www.plm.automation.siemens.com/global/ru/webinar/digital-twin-solution-for-machine-manufacturing/95925

2021, Volume 5, Issue 2, 8-17, DOI 10.6723/TERP.202112_5(2).0002

[2] Motion Capture System, 2021, https://erivantsev.wixsite.com/mocaptsystem/gallery
[3] Gregor M., Horejsi P., and Michal Š., 2015, Case study: Motion capture for ergonomics, *Innovation Vision 2020: from Regional Development Sustainability to Global Economic Growth*, pp. 468-476.
[4] Igelmo V., Syberfeldt A., Högberg D., Rivera F., and Luque E., 2020, Aiding Observational Ergonomic Evaluation Methods Using MOCAP Systems Supported by AI-Based Posture Recognition, *6th International Digital Human Modeling SymposiumAt: Volume: 11 of Advances in Transdisciplinary Engineering*, Skövde, Sweden.
[5] Hu H., Cao Z., Yan X., Xiong H. and Lou Y., 2021, Performance Evaluation of Optical Motion Capture Sensors for Assembly Motion Capturing, *IEEE*, pp. 61444 – 61454.
[6] Silva L., Rosa C., Paulo I., Mattos N., Giracca C., Merino G., and Merino E., 2020, Ergonomic Assessment of Musculoskeletal Risks in Postal Workers Through Motion Capture, a Case Study, In: International Symposium on Occupational Safety and Hygiene: Proceedings Book of the SHO2020, *Sociedade Portuguesa de Segurança e Higiene Ocupacionais (SPOSHO)*.
[7] Hiserman J., 2020, The Use of Motion Capture Technology to Aid in the Reduction of Injuries in the Work Place, *Journal of Ergonomics*, 10(4).
[8] Maurer-Grubinger C., Holzgreve F., Fraeulin L., Betz W., Erbe C., Brueggmann D., Wanke E., Nienhaus A., Groneberg D. and Ohlendorf D., 2021, Combining Ergonomic Risk Assessment (RULA) with Inertial Motion Capture Technology in Dentistry—Using the Benefits from Two Worlds, *MDPI Sensors* 21(12).
[9] Feldmann F., Seitz R., Kretschmer V., Bednorz N., and Hompel M., 2019, Ergonomic Evaluation of Body Postures in Order Picking Systems Using Motion Capturing, *2019 Prognostics and System Health Management Conference (PHM-Paris)*, 2019, pp. 204-209.
[10] Bulgarian Association of Ergonomics and Human Factors (BAEHF), 2021, https://baehfofficial.wixsite.com/baehf
[11] Federation of the European Ergonomics Societies (FEES), 2021, Ergonomics Redefined - Summer University on Ergonomics, http://ergonomics-fees.eu/node/283
[12] European Agency for Safety and Health at Work (EU-OSHA), 2021, OSH events. 34th Summer University on Ergonomics. DATE: 07/07/2021 to 09/07/2021, https://osha.europa.eu/en/oshevents/34th-summer-university-ergonomics
[13] Montesquieu Institute - Netherlands, 2021, 34th Summer University on Ergonomics, Budapest, https://www.montesquieu-institute.eu/9353000/1/j9vvj72dlowskug/vlk459ic5yzu?ctx=vi03gxem3fzg&start_tab0=11&tab=1#p1
[14] Siemens, 2021, Siemens Tecnomatix software’s Motion Capture Toolkit. Human-Centered Design & Simulation, https://www.plm.automation.siemens.com/global/en/products/manufacturing-planning/human-centered-design-simulation.html
[15] XSENS technology, 2021, https://www.xsens.com/products/mvn-animate
[16] ViveLab techology, 2021, https://www.vivelab.cloud/software
[17] Xsens Motion capture file processed in ViveLab, 2021, https://www.youtube.com/watch?v=r_STtzdxwHY
[18] Adobe Mixamo, 2021, https://www.mixamo.com/
[19] Rokoko Studio, 2021, https://www.rokoko.com/studio/studio-live
[20] Blender 3D, 2021, https://www.blender.org/
[21] [Maxon Cinema 4D, 2021, https://www.maxon.net/en/cinema-4d
[22] Autodesk 3DS Max, 2021, https://www.autodesk.com/products/3ds-max/overview
[23] Autodesk Maya Software, 2021, https://www.autodesk.com/products/maya/overview
[24] MakeHuman, 2021, http://www.makehumancommunity.org/
[25] MB-LAB. Open Source Character Creation, 2021, https://mb-lab-community.github.io/MB-Lab.github.io/
[26] MB-Lab documentation, 2021, https://mb-lab-docs.readthedocs.io/en/latest/about.html

2021, Volume 5, Issue 2, 8-17, DOI 10.6723/TERP.202112_5(2).0002

[27] Dovramadjiev T., 2019, Blender software. Rigging & Animation of 3D Human Model, https://www.researchgate.net/publication/330858265_Blender_software_Rigging_Animation_of_3D_Human_Model
[28] CMU Graphics Lab Motion Capture Database, 2021, https://www.re3data.org/repository/r3d100012183