Investigating the Possibilities of 4D Scanning Technology to Analyze the Dynamic Fit and Comfort of Karate Uniforms "Karate-Gi"

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Abstract

The objective of this research work is to investigate the possibilities of 4D body scanning technology to analyze both the karate practitioners (Karateka) body shape and measurements during specific movements as well as the dynamic behavior and fit of their uniforms (Karate-Gi). That's in the aim to design more suitable/comfortable Karate-Gi for various cases and situations, meeting karateka's specific needs and requirements and improving their performance. We present in this paper the scanning process and protocol, the generated and exported data as well as some first results and conclusions. Indeed, we started by using the 4D scanner "MOVE4D by IBV" to capture a karateka test person both in static poses as well as while performing a simple/short karate basic technique, in three situations: Minimally Clothed; Partially Clothed and Fully Clothed. Then, we processed raw scans to export various data from MOVE4D's processing software such as the karateka 3D homologous meshes, the rigged animated 3D karateka body models and a set of both static and dynamic measurements. All of these data were processed by using dedicated softwares such as MeshLab and CloudCompare to analyze dynamic shape and measurements of the karateka body in motion, the dynamic deformation of the karate-Gi's elements (pant and vest) as well as their physical fit both in static and dynamic poses.
Finally, we are also working on using the obtained rigged animated 3D karateka avatars to virtually simulate the dynamic fit and deformation of the studied karate-Gi, with 3D garment's virtual design and simulation softwares like VStitcher and Clo3D.

Keywords: MOVE4D; Karateka body; 3D meshes; 3D animated body models; Dynamic shape and measurements; Karate-Gi; Dynamic deformation and fit.

1. Introduction

Recently developed 3D human body scanning overtime technologies, called temporal scanners or 4D scanners, enable automatic markerless 3D acquisition of human body shapes in motion at ultra-high spatial and temporal resolution. They can generate accurate high-speed digital 3D body models in motion with high spatial resolution, in the form of noise- and artefact-free watertight dense meshes provided with point-to-point correspondence interframe called 3D homologous meshes, and automatically extract some static and dynamic body metrics. These outcomes can be applied to different research areas such as clothing, biomechanics, health, video games and cinema, with endless possibilities for product design, evaluation and virtual simulation. [1,2]
In clothing field, many researchers are recently exploring and studying all the possibilities of 4D scanners in the objective of much more understand garment's dynamic deformation, fit and interaction with body during each end-use specific movements, with reference to their design and material characteristics [3,4]. And thus, propose to the clothing industry efficient solution to ensure not only the desired aesthetic appearance, but also the required functionality as well as the needed wear comfort of the garment during motion, which is an extremely important issue being not considered until now especially for workwear and sportswear that should not limit the range of movement.
Therefore, some researchers are using 4D body scanning systems to visualize, analyze and evaluate both the garment dynamic behavior and its interaction with human body during motion, and investigating their application for the design of more suitable/comfortable every-day, traditional, as well as technical clothing such as protective and sports garments [3,4,5,6,7,8,9,10]. Other researchers are developing solutions to virtually simulate clothes on animated person-specific avatars, which will provide a basis for adapting their fabric characteristics and pattern design to the desired functionality and comfort without having to go through an extensive/expansive physical trial and error phase [11,12,13,14]. While other works are focusing on the development of methods for automatic analysis of the clothing related body dimension changes during motion (dynamic anthropometric measurments), since the variability of the body shape and dimensions during movement is crucial information not yet considered in garment development to achieve good fitting, comfort, mobility and performance [15,16,17,18].

In this research work, we investigated the possibilities of applying 4D body scanning technology to analyze both the karate practitioners (called "Karateka" in Japanese) body shape and measurements during karate specific movements as well as the dynamic behavior and fit of their uniforms (named "Karate-Gi" in Japanese). Indeed, during practice, Karateka wear Karate-Gi consisting of a white pant and long jacket tightened with a belt which are commonly made of cotton, cotton/polyester, or even polyester more or less heavy woven fabrics and are designed to provide both special traditional look as well as sufficient wear comfort and durability [19,20]. Furthermore, the Karate-Gi must allow for maximum freedom of mobility when doing the various karate specific punches, kicks and movements. To ensure that karateka can perform their best during rigorous practice sessions, Karate-Gi should not restrict motion by being too tight neither too loose to garantee ease of movement and physiological comfort. These qualities depend on the interaction between the Karate-Gi and the karateka body, which in turn depends not only on body shape and size, fabric properties and pattern design, but also on activities and movements to be performed in various situations. Therefore, in addition to examining the uniform behavior and fit in static poses as traditionally done in industry, KarateGi-body interactions must be analyzed also in dynamic poses to ensure adding to the pattern ease allowance amounts that accommodate the required range of motions without garment interference nor resistance. When karateka moves, their body shape should change, and consequently fabrics features as well as ease allowance values at various body locations should change as well, as observed in the literature especially for many other sportswear and protective clothing [3,4,9].
For that, we used the 4D body scanner "MOVE4D" [1,2] available in the scanning lab at ITM of TU Dresden to capture a karateka test person, both minimally clothed and wearing a Karate-Gi designed especially to practice Karate basic sequences of techniques called "Kata", not only in static poses but also while performing some karate basic techniques. After making 3D and 4D captures, we automatically processed raw scans to export various data from MOVE4D processing software such as mainly the karateka 3D homologous meshes, the 3D rigged animated karateka body models and a set of both static and dynamic measurements. Then, we processed all of these data by using dedicated softwares such as MeshLab, CloudCompare and Blender to analyze the dynamic shape and measurements of the karateka body in motion, the dynamic deformation of the karate-Gi's elements (pant and vest) as well as their physical fit both in static and dynamic poses. Furthermore, we still working on using the generated 3D rigged animated karateka avatars to virtually simulate the dynamic deformation and fit of the studied karate-Gi, with 3D garment's virtual design and simulation softwares like VStitcher and Clo3D. We present in this paper the scanning process and protocol, the generated and processed data as well as some first results and conclusions.

2. Methods and materials

2.1. Methods

To make both static and dynamic captures, we used the High-speed 4D body scanner "MOVE4D" developed by the "Instituto de Biomecanica de Valencia – IBV" in spain, and available in the scanning lab at ITM of TU Dresden in germany, which enable automatic markerless 3D acquisition of human body shapes in motion at ultra-high spatial and temporal resolution [1,2]. It's a modular photogrametry-based 3D/4D automatic capture and analysis system, consisting of a set of 12 synchronised scanning modules and a processing software to capture subjects in motion and then process, visualize and export their 3D and 2D data both in static poses and in dynamic situations (see figure 1).

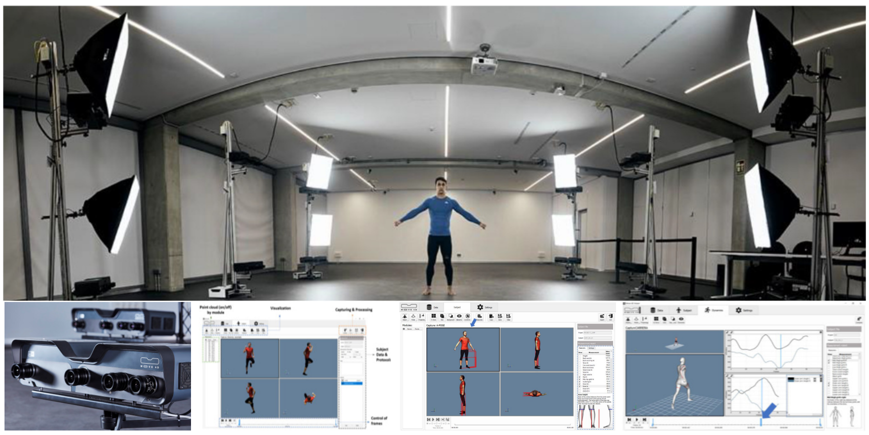


Fig. 1. Example of MOVE 4D scanning and processing system [2].

The software can automatically process raw scans to generate accurate high-speed (up to 180 frames per second) digital 3D body models in motion with high spatial resolution (less than 1 mm), in the form of 3D homologous meshes (OBJ files: one per frame) as well as 3D rigged body model of the sequence of motion as FBX animation with skeleton and multi blendshape (FBX file: one per capture). In addition to 3D outcomes, MOVE4D's software can also automatically extract a set of 93 static measurements and 19 dynamic body metrics (CSV files) [1,2].

2.2. Experimental methodology: Protocol & Workflow

We started by capturing a karateka test person both in static A and T poses as well as while performing a short sequence of two Karate basic techniques (Gedan barai + Gyaku Tsuki) as dynamic pose, in three situations: Minimally Clothed MC (without karate-Gi); Partially Clothed PC (with only karate-Gi's pant) and Fully Clothed FC (with karate-Gi's pant and jacket, tightened with a belt). We made dynamic captures at a frequency of 10 frames per second and a duration of 3-4 seconds.
Afterwards, we processed raw scans in the three situations to generate and export various data from MOVE4D's processing software such as mainely the karateka 3D homologous meshes, the rigged animated 3D karateka body models in addition to both static and dynamic measurements. Then, we processed all of these data by using dedicated softwares such as MeshLab, CloudCompare and Blender to :

- Edit the animated 3D body models;
- Visualize and analyze the dynamic shape and measurements (deformation) of the karateka body in motion as well as the dynamic deformation of the karate-Gi's elements (pant and vest);
- Evaluate both subjectively and objectively the karate-Gi's physical fit and interaction with the karateka body both in static and dynamic poses.

2.3. Materials

To make the scans, the Karateka test person worn an "Adidas kigai kata-Gi" which is a Karate-Gi designed especially to practice Kata (sequences of basic techniques) with a Japanese cut (Long jacket, short sleeves and pant), made of a cotton 100% medium-heavy brushed canvas fabric and approved by the World Karate Federation WKF for official competitions (see figure 2).

Fig. 2. Karateka test person wearing an "Adidas kigai kata-Gi".

3. Results and discussion

3.1. Captures

Figure 3 illustrate the raw scans of the captured karateka test person as visualized in MOVE4D software both in static poses (A-pose & T-pose) and in dynamic poses during a sequence of movement (sequence of two Karate basic techniques: Gedan barai + Gyaku Tsuki), in two different situations : Partially Clothed (PC) and Fully Clothed (FC).

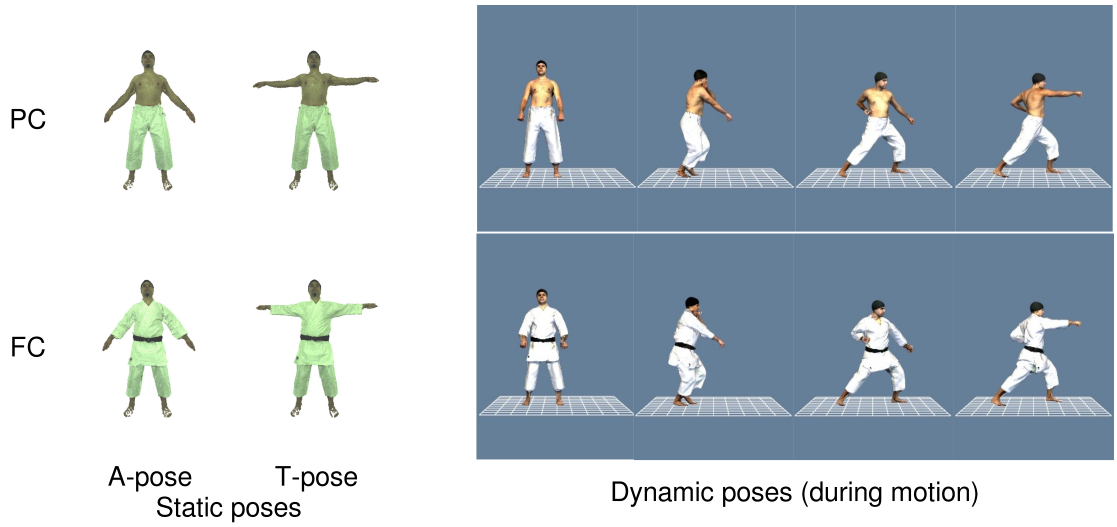


Fig 3. Raw captures both in static and dynamic poses, in Partially Clothed (PC) and Fully Clothed (FC) situations.

3.2. Raw scans: Raw 3D cloud of points

The raw scans automatically generated by MOVE4D's software as 3D raw cloud of points can be exported as one per frame Standford PLY files and visualized both in MOVE4D as well as in other 3D processing softwares like Meshlab software, in various shading and color modes. Figure 4 show the raw 3D cloud of points of the captured karateka test person both in static poses (A-pose & T-pose) and in dynamic poses while performing the same sequence of Karate basic techniques, in three different situations: Minimally Clothed (MC), Partially Clothed (PC) and Fully Clothed (FC) situations, as displayed in Meshlab.

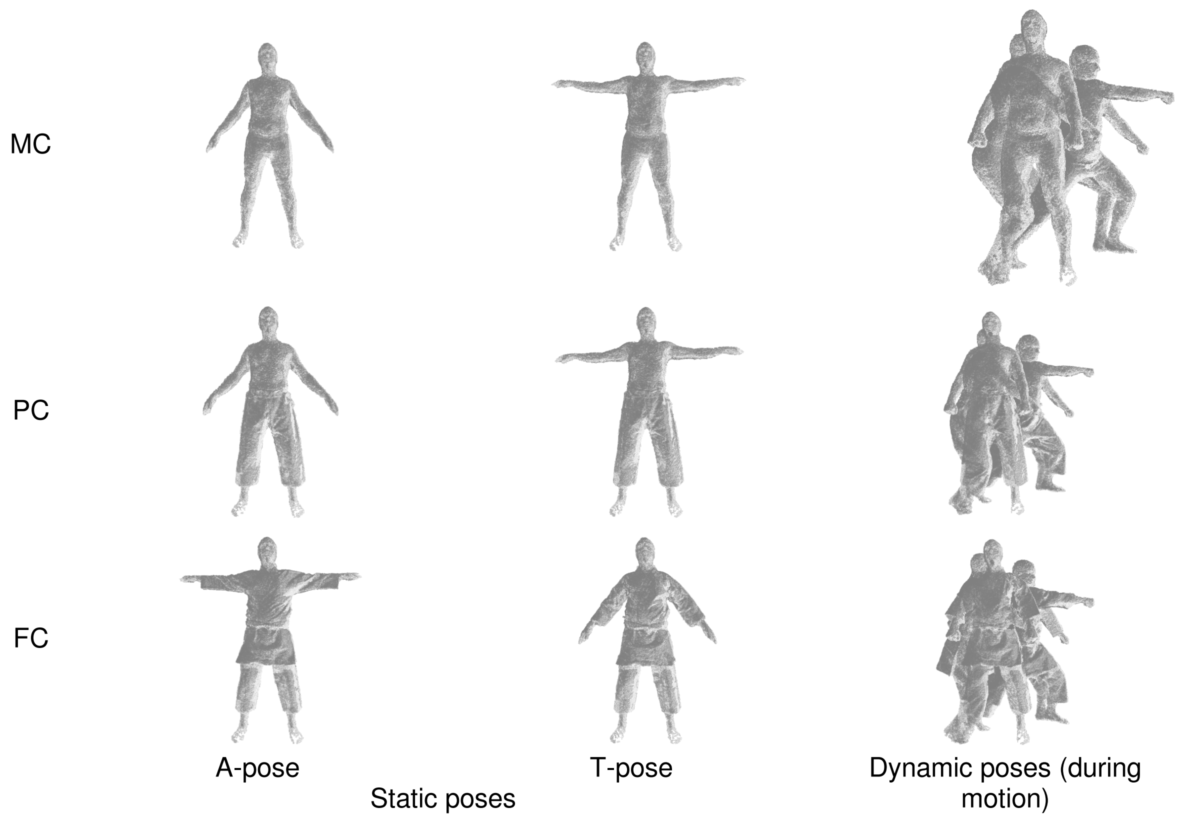


Fig 4. Raw 3D cloud of points both in static and dynamic poses, in Minimally Clothed (MC), Partially Clothed (PC) and Fully Clothed (FC) situations, as displayed in Meshlab.

3.3. Generated and extracted data

3.3.1. Processed scans: 3D Homologous meshes

Raw scans were automatically processed in MOVE4D's software to generate 3D Homologous mesh points as one per frame Wavefront OBJ files, which can be visualized as polygonal models both in MOVE4D as well as in Meshlab with points and edges in various shading, color and width attributes. Figure 5 show the generated 3D homologous meshes of the captured karateka test person in various poses and situations as cloud of mesh points. Although, Figure 6 illustrate the same 3D Homologous models displayed rather as mesh points.

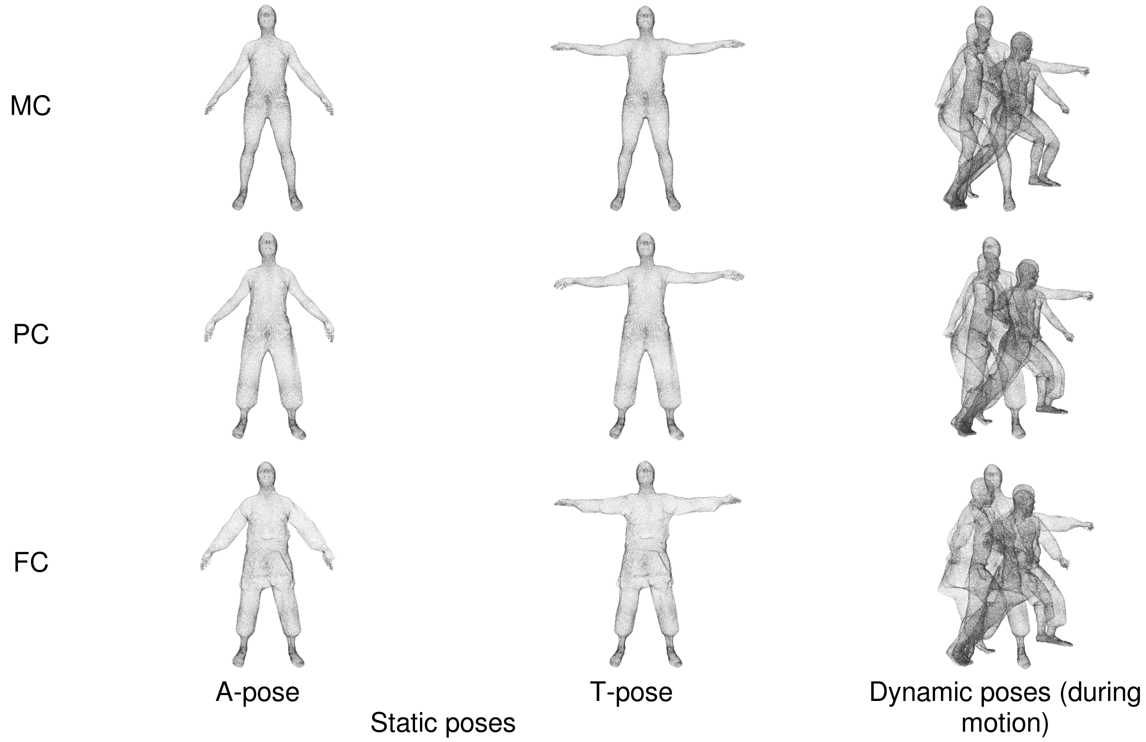


Fig 5. The generated 3D homologous models displayed as cloud of mesh points in Meshlab.

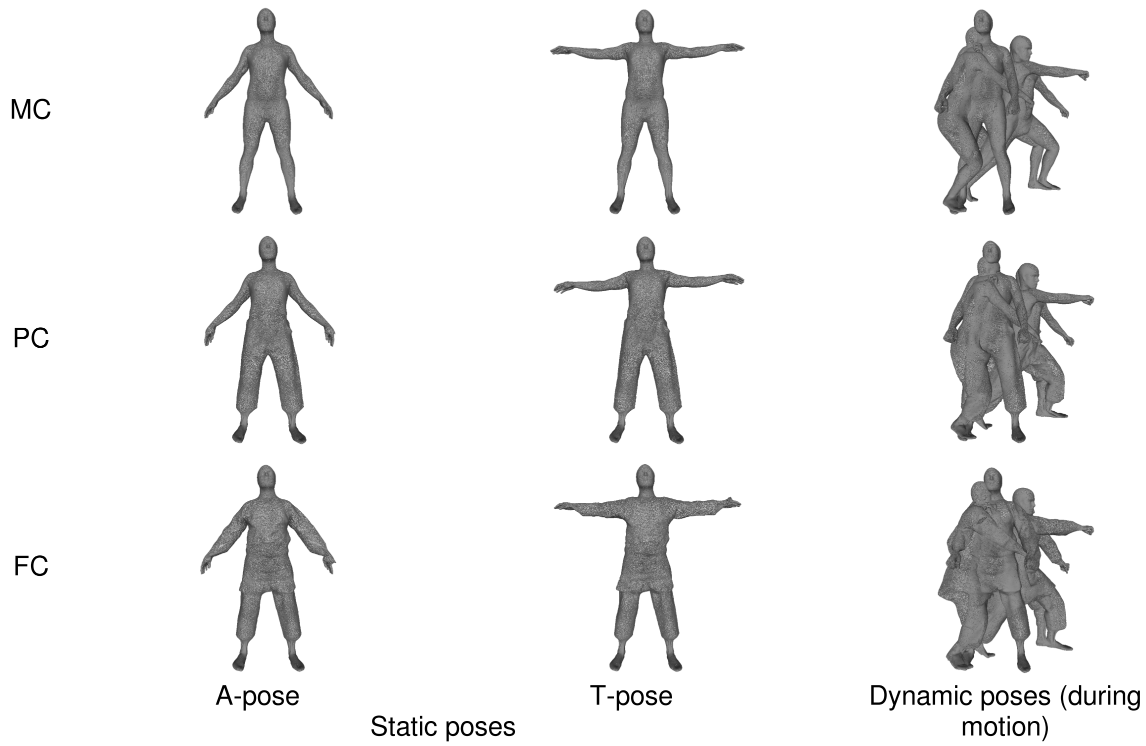


Fig 6. The generated 3D homologous models displayed as mesh points in Meshlab.

3.3.2. Processed scans: 3D rigged animated karateka avatars

For the dynamic pose, animation with skeleton and multi blendshape were automatically generated in MOVE4D's software as one per capture FBX files, especially for the minimally clothed situation (MC). These files were imported in Blender software to edit rigged animated 3D karateka test-person avatars useful to virtually simulate and develop Karate-Gi, with 3D garment's virtual design and simulation softwares like for instance V-Stitcher and Clo3D.

3.3.3. Extracted static and dynamic measurements

In addition to 3D and 4D outcomes, a set of 93 static measurements were computed automatically in MOVE4D's software for the 3D homologous meshes in A-pose. You can see in the following histogram (figure 7) the values of a selection of the most significant static measurements for the considered situations which are useful later for comparison between situations to compute the static gap between karate-Gi's components and karateka body.

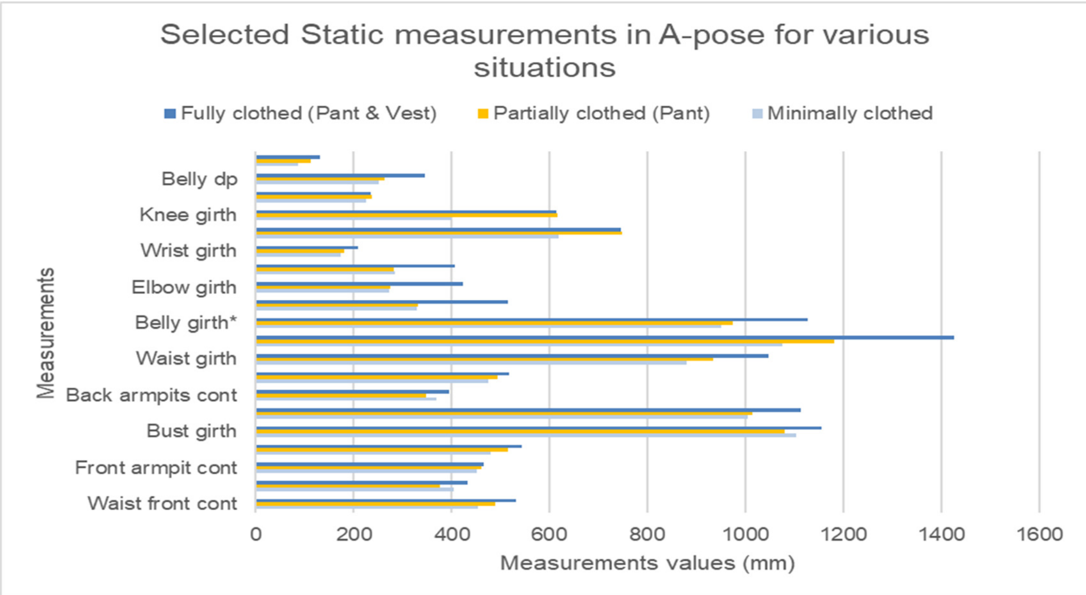


Fig 7. Values of a selection of the most significant static measurements in various situations.

Furthermore, a set of 19 Dynamic metrics were automatically computed within the version 1.5 of Move4D's software along the sequence of 3D homologous meshes of the captured subject during motion, in two different situations: Minimally Clothed (MC) and Fully Clothed (FC). You can see in figure 8 the evolution of a selection of the most significant dynamic measurements for the considered situations which are useful later for comparison between fully clothed and minimally clothed karateka models to compute the dynamic gap. Figure 9 show for instance the evolution of the Upper arm girth and Lower thigh girth values during the sequence of the movement both for the karateka body in these specific places and the karate-Gi elements in the same places.

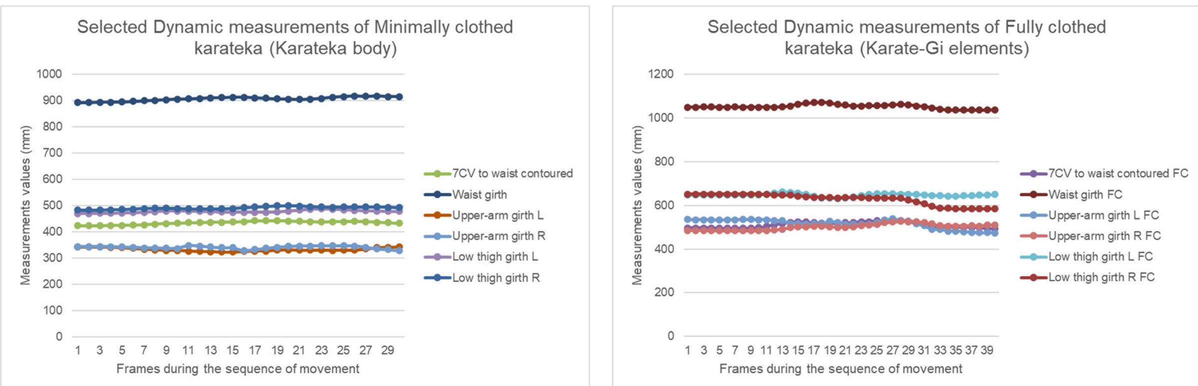


Fig 8. Evolution of a selection of the most significant dynamic measurements along the sequence of movement in Minimally Clothed (MC) and Fully Clothed (FC) situations.

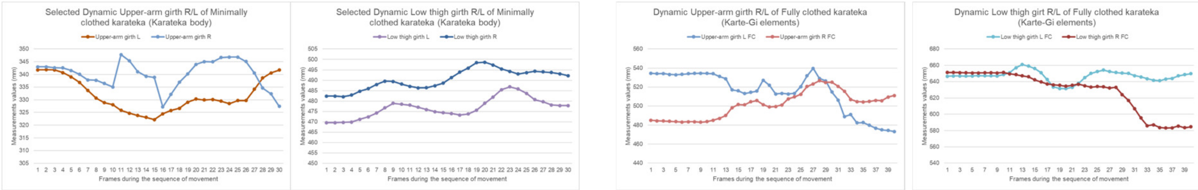
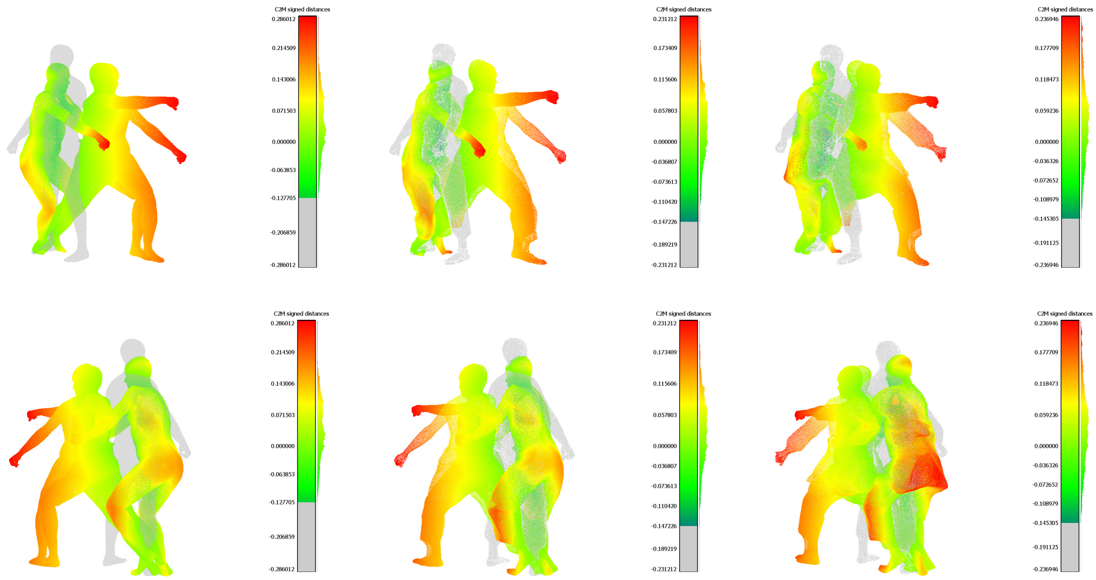


Fig 9. Evolution of a selection of the most significant dynamic measurements along the sequence of movement in Minimally Clothed (MC) and Fully Clothed (FC) situations.

3.4. Dynamic 3D Behavior

To analyze the dynamic 3D Behavior of both the karateka body and the Karate-Gi's elements, 3D maps of deformation were generated on Cloudcompare software by computing distances between point clouds of the 3D homologous meshes of both minimally clothed (MC), partially clothed (PC) and Fully clothed (FC) karateka, from frame to frame during the sequence of movement, so that we can visually evaluate the relative movement of the overall karateka body and Karate-Gi's elements cloud of points from various points of view. Figure 10 illustrates the 3D maps of deformation of the karateka body as well as the pant and jacket of the karate-Gi along the sequence of movement.



MC PC FC

Fig 10. 3D maps of deformation of karateka body (MC) and karate-Gi elements (PC & FC), along the sequence of movement from various points of view.

Furthermore, the extracted dynamic metrics are also useful to objectively analyze and consider how some specific measurements of both the karateka body and the karate-Gi change during motion (See figures 8 and 9).

3.5. Karate-Gi's physical fit

To evaluate the Karate-Gi's physical fit and interaction with karateka body both in static poses and especially in motion, 3D maps of distances were generated on Cloudcompare by computing distances and their distribution between the karate-Gi and the karateka body 3D meshes both in static T-pose in addition to dynamic situation, for instance in some selected frames during the movement. So that we can visualize and analyze the evolution of 3D air gap areas as well as areas in the karate-Gi restricting mobility (under stress), from various points of view (See figure 11).

The extracted dynamic metrics are useful as well to compute and thus objectively analyze and consider the evolution of the gap, especially the circumferential gap, between Karate-Gi's elements and Karateka's body in some selected measurements during the sequence of movement. Figure 11 illustrates the evolution of the circumferential gap between Karate-Gi's elements and Karateka's body in some selected measurements during the sequence of movement.

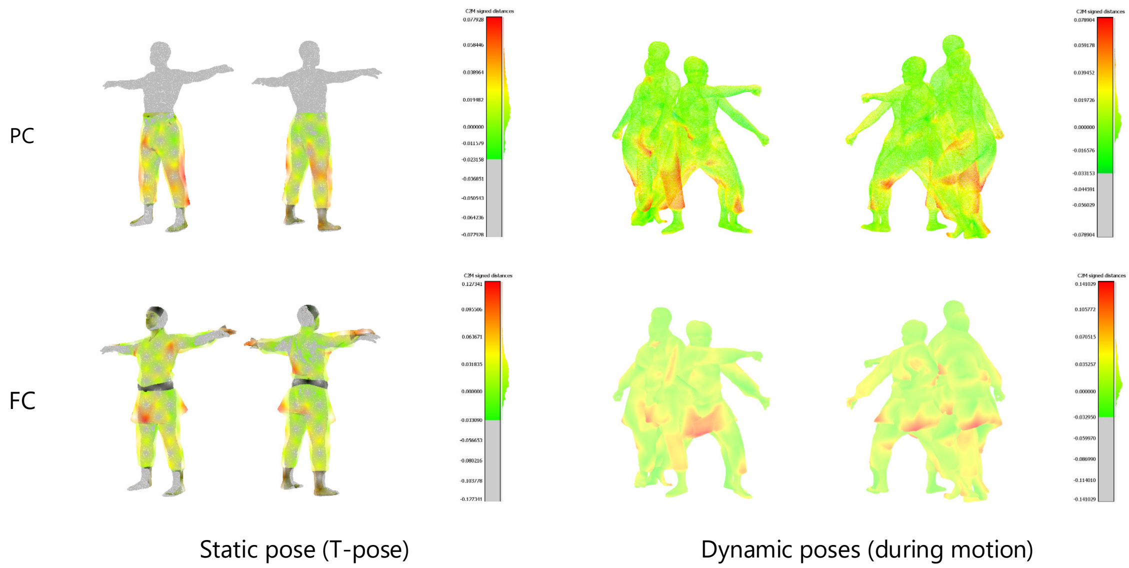


Fig 10. 3D maps of distances (gap & interference) between karate-Gi's elements (PC & FC) and karateka body (MC) both in static T-pose and during motion from various points of view.

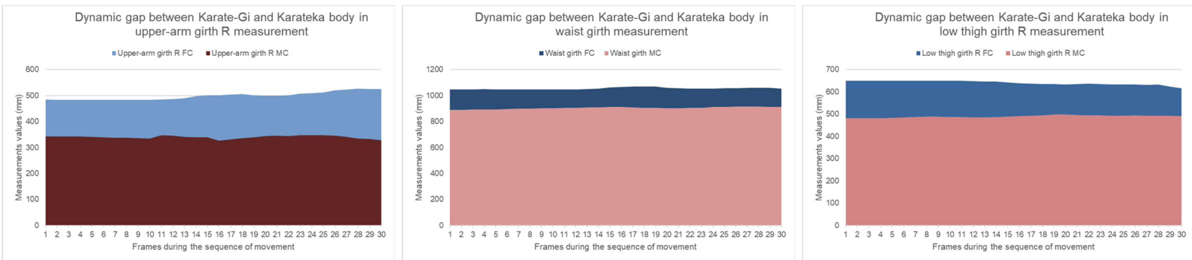


Fig 11. Evolution of the circumferential gap between Karate-Gi's elements and Karateka's body in some selected measurements during the sequence of movement.

All of these first results can show that both the karateka body's shape and measurements and the Karate-Gi's appearance and behavior change significantly during the motion especially in some specific locations. This applies also to the Karate-Gi's elements dynamic fit and interaction with karateka body (gap and interference), especially in some locations where mobility and comfort seems to be restricted.

4. Conclusions and outlook

The data generated from 4D scans are useful to analyze and standardize the dynamic karateka body shape and Karate-Gi behavior in the aim to generate datasets with a new sizing system considering karateka body parts shape and dimension changes during motion, which would be very helpful for Karate-Gi designers and manufacturers to adjust their pattern design. Furthermore, comparing both 3D meshes as well as static and dynamic measurements of clothed and minimally clothed Karateka is useful to evaluate both subjectively and objectively the tested karate-Gi's physical fit and interaction with the karateka body both in static and dynamic situations. That's by computing not only the circumferential static and dynamic gap but also the areal and volumetric gap between the Karate-Gi elements and the Karateka body. These outcomes will be useful to examine their allowed ease of movement, which will lead to select the convenient fabric and to add the adapted pattern ease allowance amounts that accommodate the range of movements without garment interference nor resistance. Moreover, generating the rigged animated 3D karateka body models in addition to digitizing both the 2D pattern and the fabric of their Karate-Gi enable to make realistic virtual simulation of the dynamic aesthetic appearence, behavior and fit of the Karate-Gi using 3D garment simulation softwares like "Clo3D" and/or "V-Stitcher" to look at their fit and strain map during animation. This will provide a basis for virtually adapting the fabric selection and pattern design of the Karate-Gi to the desired fit and comfort, without having to undertake extensive/expansive physical trials.

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