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DEVELOPMENT OF A COMPETITIVE 3D SKI-JUMPER SUIT PROTOTYPE

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Abstract:
Up-to-date computer technologies enable expeditious and accurate development of garment prototypes by ensuring higher efficiency and accuracy of the virtual prototyping process, and become a topic of increasing interest of both, computer graphics and computer-aided design for industrial fabric or apparel production. These technologies are especially important when a garment prototype should be developed for special purpose such as ski-jumper suit. Namely, shape and size of a jumpsuit need to be individually adapted to each ski-jumper according to the exact requirements by FIS (Fédereation Internationale de Ski). The FIS requirements change annually or even more often in order to assure ski-jumpers' safety during competitive ski jumps. The conventional body measurement technique and development of ski-jumpers pattern are time consuming. In order to develop an accurate and rapid design, as well as an adaptable and quickly changeable jumpsuit, different modern technologies were used. The obtained virtual prototypes of a ski-jumper and a jumpsuit enable both - fast re-modelling according to FIS rules and expeditious development and/or simulations of a jumpsuit. All these measures are taken to improve the aerodynamic design of a suit and jumper's result.

Keywords:
Ski-jumper's suit, 3D body scanner, Atos II, Rhino 4, Netfabb, MeshLab, Optitex, Virtual prototyping

1 INTRODUCTION AND MOTIVATION

Ski jumping is a winter sport, where the ski jumper downhill to the ski jump and try to fly/jump as long as possible. At this activity the ski jumpsuit have an important part, while with it's aerodynamic form, and air permeability and surface structure of the laminated fabric, assure safety and efficiency of the jump. The form of the jumpsuit, type of material and it's production prescribes the international organization Fédération Internationale de Ski (FIS) [1] with the aim to assure the ski jumper safety. The jumpsuit pattern should be adjusted to the individual jumper [2]. Suchlike process requests from the pattern designer great struggle, while composed numerous iterative processes when preparing the basic pattern and modelling, as well as sewing of the prototypes.

The application of computer aided design (CAD) intended to garments development and theirs virtual prototyping has become an obvious trend in many of industry recently. Nowadays, the virtual prototyping allow us an accurate and rapid development of the garments, as well as an adaptable and quickly changeable garments [3,4].

Virtual garment simulation is the result of a large combination of techniques that have also dramatically evolved during the last decade. Unlike the mechanical models used for existing mechanical engineering for simulating deformable structures, a lot of new challenges arise from highly versatile nature of cloth. The central pillar of garment simulation presents the efficient mechanical simulation model, which can accurately reproduce the specific mechanical properties of the cloth.

Since the cloth is by nature highly deformable, the mechanical representation should be accurate enough to deal with the nonlinearities and large deformations occurring at any place in the cloth, such as folds and wrinkles. Moreover, the garment cloth interacts strongly with the body that wears it [5].

Three-dimensional body model is critical for the virtual try-on system and has a strong impact on complexity and effect of a garment simulation. Therefore, the study of 3D body modelling has a great potential in both research and application. It is well know that commonly used methods include non-uniform rational basis spline (NURBS), manual modelling and 3D body scanning. 3D body scanning has become prevalent since 3D scanning technology is introduced into garment industry. It provides a realistic 3D body model on the basis of raw body scan data.

The development of a specific sportswear for professional purposes, such as competitive ski jumper suit, should base on the virtual prototyping and real simulation of garment behaviour in virtual environment on real 3D body model, gained by scanning technology. This allows us an effective individual treatment of a sportsman and effective development of a competitive jumpsuit taking into account the changeable demands. Since because of the safety reasons the FIS requirements for jumpsuit construction change annually or even more often, the main aim of the research is to introduce an accurate and rapid process for development of the individual ski jumper suit.

2 EXPERIMENTAL

In order to introduce the development process of the competitive jumpsuit prototype, different activities, e.i. 3D scanning of the professional ski jumper's body and determination of body measures, jumpsuit pattern design, reconstruction of the 3D body model and jumpsuit simulations were done by using measured mechanical properties of the laminate for jumpsuit, Figure 1. Furthermore, the real jumpsuit was sewn according to the FIS demands with the intention to made a comparison between the real and virtual jumpsuit prototype fitting.

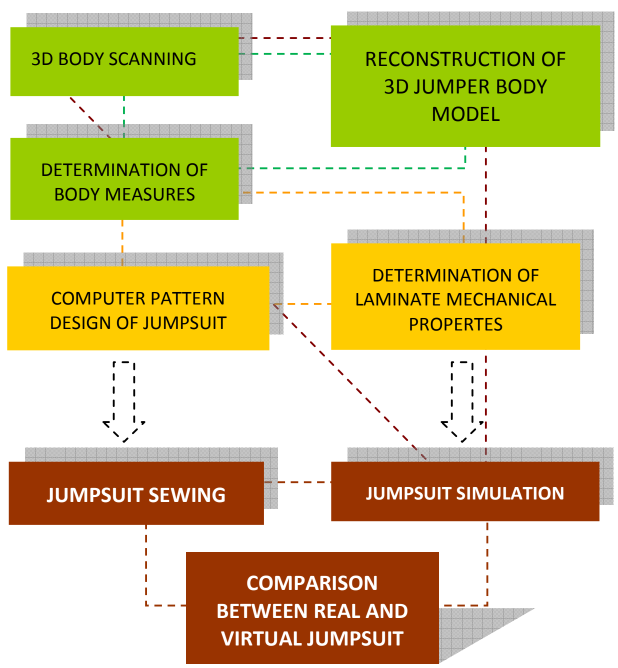


Figure 1: *Diagram of the jumpsuit development process*

2.1 3D body scanning and body measures determination

The 3D body scanning of the professional ski jumper was performed on 3D body scanner Vitus Smart at the Textile Technology Faculty, University of Zagreb, Croatia. The scanner consists of 8 cameras that provide 500 000 to 600 000 three dimensional points (point cloud). The body measures were taken using the programme package ScanWorx V 2.7.2.

2.2 Pattern design of the jumpsuit

The jumpsuit pattern design was performed according to the FIS requirements [2], Figure 2, by using the ski jumper body measures. Optitex computer programme package was used to design the jumpsuit patterns [6,7].

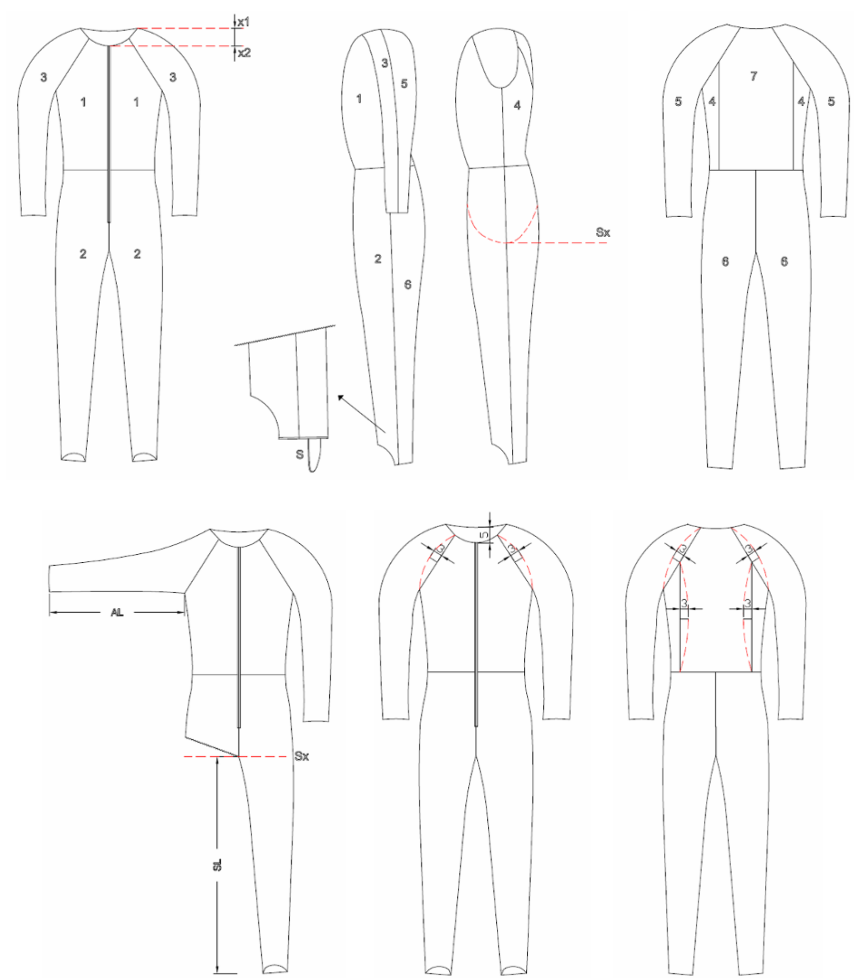


Figure 2: *Jumpsuit patterns according to FIS regulations [2]*

2.3 Determination of mechanical properties of a laminated fabric for the jumpsuit

The prototype of the ski jumper suit was made from a five-layer laminated fabric that consist of [2]:
- first layer: outer fabric,
- second layer: foam,
- third layer: elastic membrane,
- fourth layer: foam and
- fifth layer: lining fabric.

The components are laminated together by either a hot-melt process or flame lamination, where 4 acts are necessary to laminate the fabric. The outer fabric and lining fabric is a bi-elastic warp-knit fabric, called Charmeuse, which is produced on a 2-thread system warp knitting machine.
To obtain the realistic virtual prototype of the ski jumpsuit the measurements of the mechanical properties of the laminated fabric were done by using the FAST measuring system [8]. The measuring results of the mechanical properties of the laminated fabric were converted by using the Fabric Converter programme and for simulation of the laminate draping and jumpsuit fitting was carried out by OptiTex programm, Table 1.

Table 1: *Mechanical properties of the laminated fabric measured by FAST measuring system and converted properties for jumpsuit simulation with OptiTex programme*

Properties	Measured value			OptiTex parameters		
	Unit	Course d.	Wale d.	Unit	Course d.	Wale d.
Extension at load of 98,1 Nm^{-1} / E 100	%	9.6	10.9	gcm^{-2}	400.641	352.858
Bending rigidity / B	µN·m	44.8	54.5	dyn*cm	4965	
Shear rigidity / G	Nm^{-1}	199		dyn*cm	1990	
Surface thickness / ST	mm	0.035		cm	0.0035	
Mass per unit area / W	gm^{-2}	601		gm^{-2}	601	

2.4 Reconstruction of the 3D ski-jumper body model

In the first step of our research the parametric 3D body model of a ski jumper, determined with body measures obtained by the scanner, was used for jumpsuit virtual simulation. The parametric model was defined using the following measures: body high, chest circumference, waist circumference, neck circumference, length crotch-floor, high thigh circumference, knee circumference, shoulders width, shoulder slope, upper arm circumference and arm length. A great deviation between the parametric 3D body model, Figure 3a, and scanned 3D body model of the ski jumper is obvious. Therefore, we decided to use the scanned 3D body model of a ski-jumper for simulation of the ski jumpsuit prototype, Figure 3b.
The process of generation of the scanned 3D body model involved the body reconstruction. Namely, 3D scanner cannot produce sufficient scan data and lead to defect body model, Figure 3c, that influences the jumpsuit fitting. For this reason the reconstruction of the scanned 3D body model of the ski jumper was performed by using the programs Atos, Rhino 4, Netfabb and MeshLab.

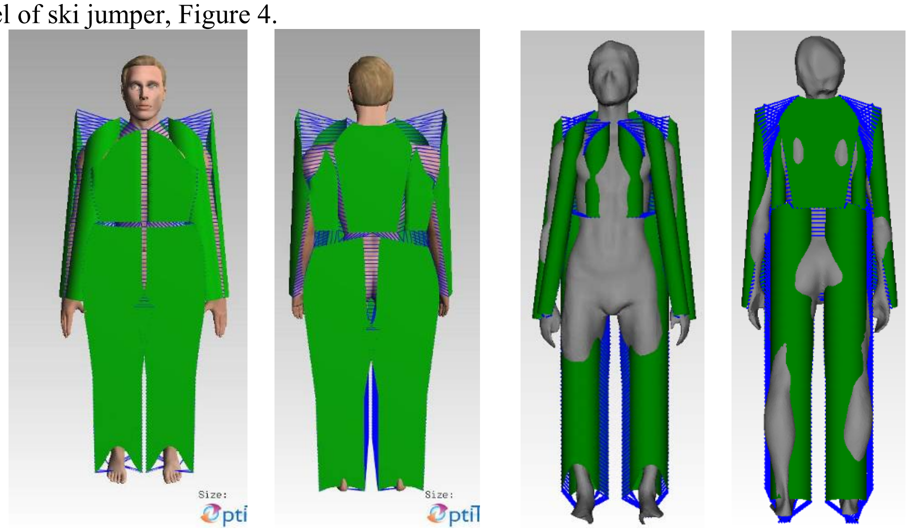
(a) (b) (c)

Figure 3: *Parametric 3D body model (a) , scanned 3D body model (b) and defected 3D body model(c)*

2.5 Jumpsuit sewing and virtual simulation

The sewing of a real ski jumpsuit by considering the FIS requirements, e.i. seams, seam allowance, zip length and width, as well as requirements for sewing the neck line, sleeve length and trouser length was carried out on a Dürkopp sewing machine 271.
For the 3D virtual simulation of the competitive prototype of the ski jumper suit it was necessary to define the jumpsuit patterns by:

- type and position of the individual pattern regarding the virtual mannequin (e.g. front part, back part, right sleeve etc.),
- measured mechanical properties of the laminated fabric for all jumpsuit patterns and
- seam lines for stitching the patterns on the (a) parametric 3D body model and (b) scanned 3D model of ski jumper, Figure 4.



(a) (b)

Figure 4: *Positioning of the jumpsuit patterns on parametric (a) and scanned 3D body model (b), and appointed seams for stitching*

Furthermore, the comparison of the ski jumper suit between the real prototype, simulated jumpsuit prototype on the parametric 3D body model and simulated jumpsuit prototype on scanned 3D body model of the ski jumper was performed.

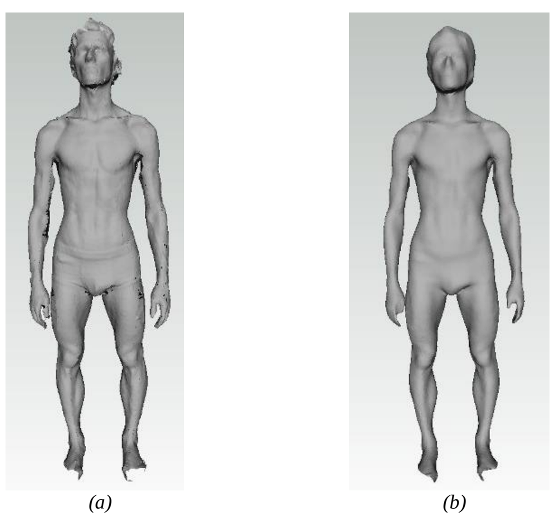
3. RESULTS WITH DISCUSSION

3.1 Results of the reconstructed scanned 3D ski jumper body model

Reconstruction of the ski jumper 3D body model was realized by different computer programmes [9-12]. Programme ATOS was used first, Figure 5. Number of polygons was reduced from about 660 000 to 150 000 triangles using the tool Thin Mesh. Then the mesh was repaired and holes were filled with the tools Repairing Mesh, Regularize Mesh, Eliminate Mesh Errors, Relax Mesh and Fill Holes. Several operations were repeated in order to reduce mesh errors. The mesh was then exported as a binary .stl file.

Figure 5: *Reducing number of polygons and repairing the mesh in programme ATOS*

Then MeshLab programme was used. Mesh imported from ATOS was still not watertight and totally uniform, Figure 6a. Therefore, a tool Surface Reconstruction: Poisson was used. This tool makes from more partly overlapped meshes one uniform average mesh. There are less details included, but we got properly mesh for further work. The mesh was then exported as a .stl file again.



(a) *(b)*

Figure 6: *Surface reconstruction*

Rhinoceros program was used after that. The whole object was scaled and properly rotated, Figure 7. Programme NetFabb Basic was used for the final test and view of the model. This was the last step before importation of the scanned 3D body model into the OptiTex programme for clothes simulation. The scanned 3D body model of the ski jumper imported in OptiTex programme is presented in Figure 8.

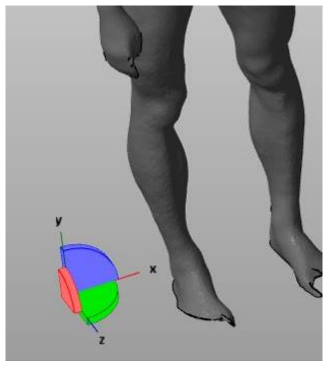


Figure 7: *Scaled and rotated object.*

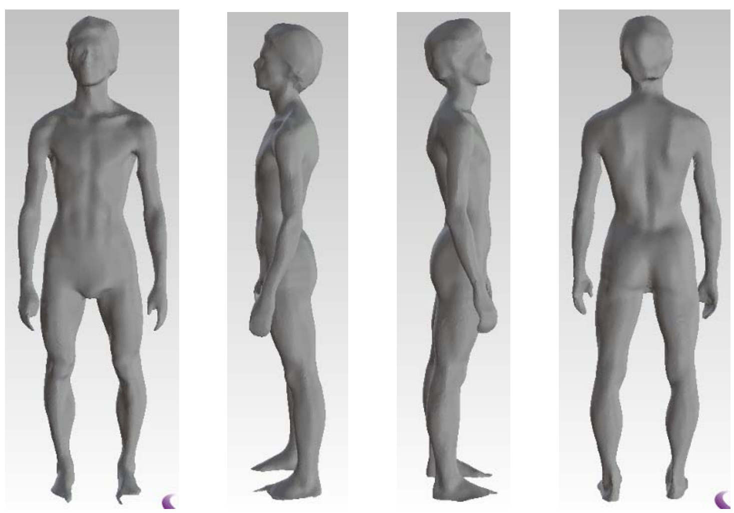


Figure 8: *Reconstructed and imported scanned 3D body model of a ski jumper in OptiTex programme*

3.2 Comparison of a real and simulated ski-jumper competitive suit

The computer simulation of the ski jumpsuit prototype and real sewing of the prototype was made. The comparison between the real prototype, simulated jumpsuit prototype on parametric 3D body model and simulated jumpsuit prototype on a scanned 3D body model of the ski jumper was done, Figures 9 to 10. For a good simulation of the jumpsuit different positioning and adjustment of the patterns regarding the parametric 3D body model and scanned 3D body model should be performed, Figure 4. The reason for this are different postures of the 3D body models. When appreciating the fitting of the jumpsuit the estimation of the neck line, shoulder area and armpit front and back, as well as form of the sleeves, trousers and waist area were carried out. The sewn jumpsuit wasn't estimated on the ski jumper, which body was scanned. The reason for this is a great absence of ski jumpers because they are most of the time preparing for the jumping season. Therefore, we used for fitting a human model with similar body measures.

The neck line on the virtual model is after simulation extended when compared with the real prototype, Figures 9 and 10. Difference arises because of the draping of the laminate in the neck area on a parametric virtual mannequin. The real jumpsuit has the neck line made with non-elastic band, Figure 11. Considering the real material properties in this area, the simulation result on the scanned 3D body model is improved, Figures 10 and 11.

The folds originates on the back part of the jumpsuit seams and sleeve seams, as well as in the armpit area. These folds present considered expansion in the seams areas (+ 1.5 cm) to achieve appropriate aerodynamic form of the jumpsuit during the jump of the ski jumper. When taking the closer view of the folds in the armpit area, we could see the additional transverse fold that reflects through the parametric mannequin anomaly in the high chest circumference, Figure 9, while this fold doesn't appear when simulating the jumpsuit on a scanned 3D body model of the ski jumper, Figure 10.

When comparing the simulated and real jumpsuits in the waist area, an additional fold in the area of waist and buttock area appears, Figures 10 and 11, while it isn't visible when simulating the jumpsuit on a parametric 3D body model, Figure 9. The appearance of the bottom part of the jumpsuit is smooth and gives us the filling of tension and discomfort, Figure 9. On the other hand the real jumpsuit and simulated jumpsuit on a scanned 3D body model of the ski jumper expresses non-stretched trousers and assures felling of a good comfort and requested width in this area, Figures 10 and 11.

The form and fitting of the sleeves are very similar on all of prototypes with the exception the shoulder and armpit area, because of the anomalies of the parametric mannequin. Additional folds on sleeves appear in elbow area. These are visible on real and simulated jumpsuit on scanned 3D body model, Figurs 10 and 11, while they are not visible on a parametric body model because of the stretched arms, Figure 9.

Figure 9: *Simulation of the ski jumper suit on the 3D parametric body model*

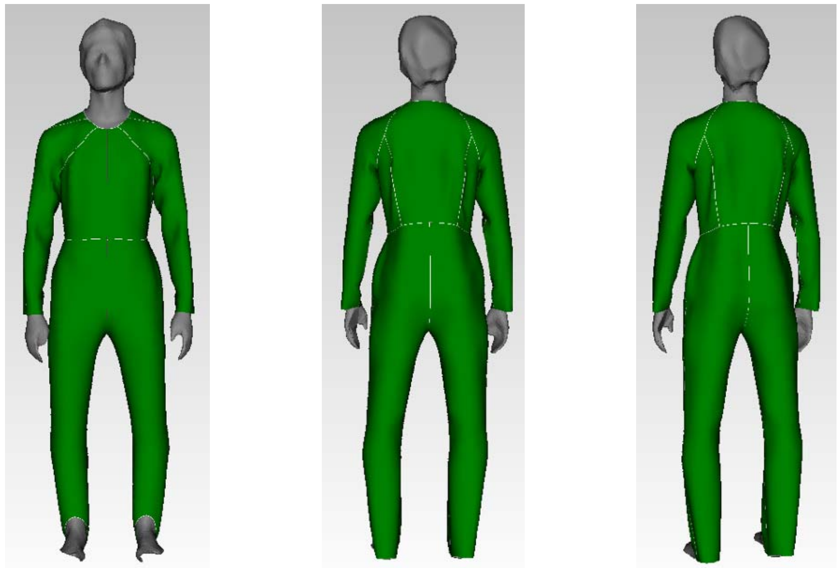


Figure 10: *Simulation of the jumpsuit on the real 3D body model of the ski jumper*

Figure 11: *Real prototype of a jumpsuit*

4 CONCLUSIONS

The process of virtual prototyping of a ski-jumper suit was presented in this contribution. Based on the analysis of a visual appearance of a virtual and real model of a ski-jumper suit it can be concluded that the differences occur above all because of significant differences in the form of a parametric body model and consequently the fitting of a laminated textile material. When using a parametric body model, we can set only certain body measures, which proved not to be enough for a realistic appearance and similarity with the real body model. Therefore, we used a scanned 3D body model of a

real ski-jumper for a better and more realistic simulation of a jumping suit. For this purpose we carried out the reconstruction of a surface of a 3D ski-jumper's body model. Then, we transformed the data into a suitable format in order to import it into Optitex programme, which enabled an efficient and realistic simulation of a suit prototype.
Cognitions, related to the deviations of the appearance and fit of a virtual and real prototype of a jump suit clearly show the need for using a real 3D body model, originating from the body scanning process, if we want to achieve improved pattern development and more realistic simulation of garments in general. This is particularly important in competitive sports, where already slight improvements in professional equipment and clothing mean a great advantage.

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