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THE GEOMETRICAL PERSONALIZATION OF HUMAN ORGANS 3D MODELS BY USING THE CHARACTERISTIC PRODUCT FEATURES METHODOLOGY

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Abstract. Computer-Assisted Surgery (CAS) involves applying various computer-based methodologies and devices to plan, guide, and perform surgical procedures, thereby improving outcomes throughout the surgical process. This study integrates the Characteristic Product Features (CPF) methodology with Method Of anatomical Features (MAF), both developed in-house to improve CAS. It enables the creation of the human organs' geometrical models by including different relations between Regions of Interest (RGIs) models and specific properties, like functional, materials, and topological. Enhancing existing methodologies in CAS aims to offer a more comprehensive geometrical description of human organs, leading to the development of more precise and anatomically accurate personalized geometrical models. Creating customized geometry with accurately defined features is expected to enable surgeons to prepare and execute surgical interventions better, consequently improving patient care and recovery. The demonstration of successful geometry adaptation is shown by prototyping developed models using 3D FDM printing.
Keywords: computer-assisted surgery, characteristic product features, method of anatomical features.

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1. Introduction

The importance of reverse engineering in medicine and industry is significant, particularly for understanding various object properties such as shape, geometry, material, color, functionality, and technology [12]. When it comes to acquiring information about an object's shape or geometry, the process involves two key activities: scanning and remodeling. Scanning typically involves using 3D scanning devices to capture geometrical data through various scanning technologies, whether contact or non-contact. The result of the scanning process is a point cloud, which consists of numerous points representing the product's surface or internal structure. This point cloud is then used in the remodeling process to create a 3D geometrical model of the scanned object. Various remodeling methods can be applied, producing precise geometrical, mathematical, or numerical representations of the models surface [1, 22]. Part remodeling is a standard component of the reverse engineering process, aiming to produce a geometrically accurate and topologically correct 3D model. The remodeling process employs various procedures and methods, which can be categorized based on the quantity and quality of the scanned data [19]. Remodeling can be performed with either complete data or insufficient data about the part's geometry. In the latter case, sources of data deficiencies can be hardware limitations (e.g., scanner capabilities) or software constraints (e.g., scanner software) [10, 19]. The specific requirements of each case influence the model's geometrical accuracy and topological correctness. Therefore, the complexity of 3D model creation process for a particular part can vary [20, 23]. The process generally involves the following steps: Importing the Point Cloud, Filtering the Point Cloud, Point cloud analysis, Initial Mesh Creation, and Surface or Solid Model Creation. This study introduces a new approach for remodeling a product's outer surface, focusing on Characteristic Product Features (CPF) [18] and Method Of Anatomical Features (MAF) [20]. These product features are crucial geometrical or functional entities specific to a particular object (human organ or a product). They allow a more product-oriented definition of model geometry. Each product feature is not only geometrically defined, with an appropriate 3D model created, but also improved by adding additional properties. These properties include functionality, manufacturing technology, and material definition, extending beyond a mathematical or geometrical description. Multi-dimensional feature definitions can include geometric descriptions (such as point cloud, STL, IGS, STEP), material definitions, and technology definitions. The presented approach enhances 3D model creation by improving geometrical accuracy, topological integrity, and functional validity. MAF introduces a novel approach to describing the geometrical entities of human bones and organs, enabling the creation of various geometrical models. With MAF, two geometrical models can be generated: classical 3D Geometrical models and Parametric models [14, 19, 20]. Parametric models can adapt to the geometry and morphology of a specific patients organ and are based on morphometric parameters acquired from medical imaging methods. MAF has been proven effective, as demonstrated by its successful application in creating geometrically accurate and anatomically correct models. One of the main benefits of these model's applications is that they can be customized to the requirements of specific clinical cases. For example, in one case, a sternum implant was created using MAF [16] and additive technologies and successfully implemented in a patient.

The enhancements proposed in this research, particularly the integration of the CPF, expand MAFs capabilities to define more complex models with additional properties. An essential aspect of CPF is the ability to parametrize the point set, creating a parametric point cloud model that can adapt to different parameters, including geometric, functional, and technological characteristics. The application of CPF is demonstrated in creating a 3D-printed ski shoe heel lip model, where functional, geometrical, topological, and material features were defined, influencing the creation of the heel lips geometrical and physical model. The resulting Features Model (FM) [8] from MAF and CPF can meet various needs and fulfill different requirements, serving as an input model for further processes and enabling better parameterization according to novel specifications.

The applications of the CPF and MAF are wide, but they can be explicitly used in Computer-Assisted Surgery (CAS) or Computer-Assisted Orthopedic Surgery (CAOS) [2, 3]. CAS encompasses a range of techniques that utilize computers and other devices for preparation and execution of surgical procedures. A key component of CAS is the creation of an accurate, personalized model of the affected organ (e.g., tendon, ligament, or bone). Generally, these models are developed using one of two approaches. The first approach involves medical imaging technologies such as Computed Tomography (CT) or X-Ray to generate 3D geometrical models of human organs [13] by using software integrated into medical scanners and/or post-processing medical images in CAD [4]. However, this approach can be limited in cases where the scanned organ is incomplete due to illness (like osteoporosis, arthritis, or cancer) or trauma (such as multiple fractures, crushed bones, or torn ligaments and tendons), or when the medical images are of insufficient quality. The second approach involves creating 3D geometrical models based on predictive geometrical or statistical models. In predictive models, geometric entities are described using mathematical functions whose arguments are morphometric parameters obtained from medical images, allowing the creation of accurate, patient-specific organ models. The MAF with integrated CPF can be utilized in both approaches. These methodologies are applied through the detailed definition of a geometrical and parametric model of the Anterior Cruciate Ligament and InternalBrace [21], considering anatomical and morphological properties, functional and material characteristics, and parametric definition, including the anatomical points formation. The main idea is to present how a product features-oriented methodology (CPF) can improve a pure medical method like MAF. The crucial benefits reflect the possibility of creating a more detailed geometry, manufacturing, material, functional, and other (required) models. This approach will significantly improve the process of patient treatment and recovery by enabling the integration of better planning and execution of surgical interventions, faster implants, and other surgical material provision, as well as a higher level of recovery monitoring and control.

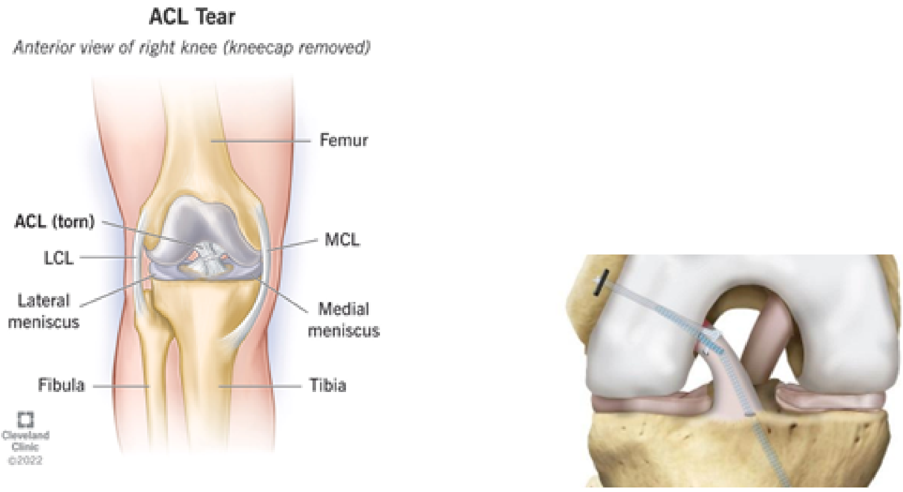
The paper is structured in two main sections. The first section describes ACL and the issues that this research tries to overcome. The second section is oriented to the development of geometrical and 3D printing models and discusses future work.

2. Method application for Anterior Crucial Ligament remodeling

In this research, the Anterior Cruciate Ligament (ACL) [8] is an example of knee ligament remodeling based on various requirements defined within the CPF model. The knee joint is composed of three bones: the femur (thighbone), tibia (shinbone), and patella (kneecap), with the patella protecting the front of the joint. Four primary ligaments act like strong ropes to stabilize the knee by connecting these bones: the medial collateral ligament (MCL) on the inside and the lateral collateral ligament (LCL) on the outside. A detailed explanation of these ligaments is available in [8]. One of the most common knee injuries is an ACL sprain or tear. The traditional method of ACL repair involves using tendon grafts secured with screws in the femur and tibia - a technique that has been employed for years with varying results. As presented in [6, 9], a novel approach suggests using an InternalBrace for ACL repair (Fig. 2.1), which offers significant advantages. Early repair with an InternalBrace helps protect joint health and restore normal biomechanical function, reducing the need for cartilage resection. Traditional ACL reconstruction using hamstring tendons is associated with a high risk of arthritis, with studies reporting rates as high as 48% after ten years. With the InternalBrace, more than 80% of patients did not require additional reconstructive surgery within five years of follow-up. For those who did need further surgery, recovery was still excellent after a second-stage revision supported by InternalBrace. The primary difference between traditional ACL reconstruction and the InternalBrace approach is that the latter is much less traumatic to the joint. InternalBrace repair involves only small bone tunnels (2 mm), unlike the larger tunnels required for traditional reconstruction (2.4 mm for the femur and 3.5 mm for the tibia). This results in significantly less bone trauma with the InternalBrace method. To create a personalized 3D model of the ACL, it is essential to define the functional characteristics of the chosen treatment approach. Given the promising outcomes, this research focuses on the InternalBrace method. Complications in ACL reconstruction can arise from pre-operative decisions, intraoperative factors, and postoperative issues.

This study addresses pre-operative and postoperative complications, which can be mitigated through thorough pre-operative analysis of the injured knee. Potential complications are defined in [3] and they can include:

- Intraoperative Complications:
  - A kneecap (patella) fracture may occur during surgery when a bone-patellar-tendon-bone (BPTB) graft is harvested. This can result from improper bone cuts during graft harvesting.
  - Improper harvesting of the hamstring graft can lead to a small graft or knee bending weakness. Excessive harvest may weaken the hamstring



(a) The knee anatomy (b) The internal brace and ACL

Fig. 2.1: The Knee Anatomy and InternalBrace [9]

muscle, leading to knee flexion weakness. Injury to the saphenous nerve during skin and tissue cutting can cause numbness and tingling on the inner knee joint.

- There is a risk of damaging major blood vessels and nerves behind the knee, potentially leading to amputation or foot paralysis.
- ACL graft mismatch can occur if the graft size doesn't match the tunnels, causing instability or stiffness. Incorrect tunnel placement may lead to instability, loss of knee flexion or extension, knee pain, or graft rupture.

• Postoperative Complications:

- Stiffness, defined as an incomplete range of motion after surgery, can result from poor surgical technique or inadequate postoperative rehabilitation. Treatment may include aggressive rehabilitation, manipulation under anesthesia, or arthroscopic adhesiolysis.
- Patella fractures after ACL reconstruction, often due to graft harvesting, may require surgical intervention.
- Infection can lead to pain, swelling, redness, elevated temperature, and stiffness. Diagnosis may require radiological imaging, knee aspirate, and cultures. Treatment may involve lavage, antibiotics, debridement, and in some cases, graft removal.
- Pain in the front of the knee after surgery, often associated with a patellar tendon graft, may also occur with allograft or quadriceps tendon grafts,

possibly due to noncompliance with the postoperative rehabilitation protocol.

These complications represent the basis for the creation of the CPF/FM model, which outlines the functional and geometrical requirements that the 3D ACL model must meet. Satisfying these requirements will lead to better definition, creation, and application of the ACL implant. The personalized 3D model, developed during pre-operative planning, will feature precise geometry and accurate positioning of the femur and tibia holes and the InternalBrace dimensions, aiding surgeons in proper InternalBrace implantation. This approach reduces the need for tendon grafts and minimizes risks such as patella fractures and infections. Key geometrical requirements based on the identified complications for this clinical case include:

- accurate geometry of the femur and tibia, with the anatomical axis aligned in the Anterior-Posterior (AP) plane [12];
- a geometrical model of the ACL, emphasizing positional accuracy [21];
- a sheet model (3D model with minimal thickness) of the bracelet;
- a parametric model of the bracelet The model which can adapt to the specific patient geometry;
- a 3D-printed model of the bracelet and a knee to test surgical procedure.

The MAF method already provides procedures for creating accurate, personalized geometrical models of the femur, tibia, and other bones, which can serve as the foundation for developing an ACL model(s) from a CT scan. In this case, a knee model from Clinical Center Nis, Serbia, scanned in resolution 512x512, 0.5 mm slice thickness, was used for developing the geometrical models of the ACL and InternalBrace. The FM (CPF) created for the InternalBrace incorporates geometrical, functional, material models and geometrical parametric model. The bracelet's geometrical model is defined using pre-existing geometrical models of the tibia and femur, with two axes constructed (Fig. 3.1) to determine the InternalBraces insertion direction through these bones [21]. Functional requirements were outlined earlier, while the material is specified according to clinical application (FiberTape suture - polyethylene). By developing this type of FM, designers, and surgeons have the flexibility to make modifications and better prepare for and conduct surgical interventions. The parametric model is created using geometrical points, which are anatomically significant for the creation of the ACL model and InternalBrace. The importance of the brace parametric geometry is reflected in the possible use of different (more rigid) materials for its creation, like elastomers (plastic, rubber), with predefined or tailored geometry. In essence, the presented work is an extension of the initial research demonstrated in [21], and it adds a more detailed approach to geometry specification and construction and the formation of the different models, including the ACL parametric model. The procedure for creating the ACL and Brace surface and parametric models is described in the following section.

3. The 3D models of the ACL and internal Brace

This section defines the procedure for creating the ACL and InternalBrace geometrical models. It includes a description of the applied geometrical entities, essential definitions, the geometry creation (construction) process itself, and parametric model definition and future activities.

3.1. The Basic Geometry

NURBS, short for Non-Uniform Rational B-Splines, are a type of curve related to Bezier curves. A NURBS curve is defined by four key elements: its degree, control points, knots, and an evaluation rule, all of which are determined through a mathematical formula. In essence, NURBS are used to mathematically represent complex 3D geometry. While NURBS themselves are not surfaces, you can create NURBS surfaces [11] by connecting NURBS curves. NURBS Modeling involves creating detailed and flexible free-form 3D models by using geometrical shapes like 2D lines, circles, and arcs, all defined through complex mathematical equations. NURBS models are known for their high accuracy and flexibility, making them ideal for surface modeling in a variety of applications, including complex animations, detailed illustrations, and designs intended for production. NURBS geometry has several key qualities that make it ideal for computer-aided modeling: Industry Compatibility: NURBS geometry can be exchanged using many industry-standard methods, making it easy to share models with customers, who can then port them across different platforms; Future-Proofing: The accurate and standardized definition of NURBS geometry allows it to evolve with advances in 3D modeling techniques; Programmability: NURBS can be programmed for applications in engineering, software development, industrial design, and more. Custom software solutions can also be developed using NURBS; Precision: NURBS can precisely represent both standard and freeform geometric shapes, including linear, circular, ellipsoid, spherical, or toroidal forms, as well as complex shapes like human or vehicle bodies; Efficiency: NURBS geometry requires significantly less data to represent complex shapes compared to common faceted approximations, and the evaluation rule for NURBS can be accurately and efficiently implemented on any computer.

SubD objects are mesh-based and are ideal for more approximate modeling tasks, such as character modeling and creating smooth, organic forms [15]. Subdivision surfaces, or SubDs, are piecewise parametric surfaces defined over meshes with arbitrary topology. These individual parametric surfaces are essentially collections of simpler modeling primitives known as patches. Patches act as "pieces" of a larger surface, similar to how a face or polygon represents a portion of a polygonal mesh. Parametric patches are fundamental building blocks for piecewise smooth surfaces, and various types of patches have been developed to meet the needs of geometric modeling. A patch consists of points or vertices that influence a rectangular segment of a smooth surface. The points that control the shape of the surface are known as control points, and the entire set of these points forms what is called a control mesh or control hull. The uniqueness of different types of patches lies in how the control points affect the surface. Mathematically, each control point has a "basis function" associated with it, which influences the surface when that particular point is adjusted. A set of connected patches represents piecewise parametric surfaces. One of the simplest methods to construct a surface for rectangular patches is by defining a set of patches using a rectangular grid of control points. In some cases, points can overlap in adjacent patches, meaning that moving a single control point affects multiple patches, ensuring they meet seamlessly. For B-spline patches, this overlapping ensures a smooth transition between patches, while Bezier patches only share points along their borders, making B-splines particularly effective for surface representation.

Subdivision modeling entails starting with a basic mesh and progressively subdividing it into smaller polygons to achieve smoother and more detailed surfaces. The process begins with a simple polygonal mesh, which is then repeatedly divided, adding more vertices to refine the shape. This iterative approach provides precise control over the level of detail and the overall smoothness of the surface. Unlike subdivision modeling, NURBS modeling is defined by control points, weights, and knots, offering precise control over shape and curvature. The key advantage of NURBS modeling is its ability to produce smooth and highly detailed surfaces, making it a preferred choice for industrial design, architecture, and automotive design industries. The SubD surfaces are more accessible to create and modify, but they lack the precision and geometrical accuracy of the NURBS surfaces

3.2. The Important terms and definitions

In the MAF and CPF, some specific elements must be defined, considering geometry, morphology, and anatomy. The essential elements are Anatomical Definitions, Regions of Interest (RGIs), Anatomical Points, Referential Geometrical Entities (RGEs), and Constitutive Geometrical Entities (CGEs) [19].

- Anatomical definitions: Anatomical analysis involves examining the anatomy and morphology of human bones to create a detailed anatomical model. This model serves as a semantic representation that links geometrical elements of the 3D bone model with anatomical and morphological terms established in medical literature.

- RGIs are very important for preparation and for performing surgical interventions. RGIs are specific anatomical regions defined by the medical practitioner, and they can be transferred to create RGEs or CGEs. For example, RGI is contact surfaces between bone and fixation plate. A surgeon can adapt the plate shape (bend plate) to the patient's bone before surgery, shortening the surgery time and patient recovery.

- Definition of RGEs: RGEs are fundamental geometrical entities, such as points, lines, planes, and axes, created on the polygonal model of a human bone. These entities form the basic geometry for generating other geometrical elements, like surfaces. Anatomical Points are RGEs important for the construction of CGEs; for example, they can be used to construct curves for surface model creation.

- Definition of CGEs: RGEs serve as the foundation for creating CGEs. These constitutive entities are essential for developing surface and solid models of human bones and their components aligned with the bones morphology. They are usually parametric curves like NURBS or B-splines, but any construction geometry can be considered a CGE.

3.3. The construction process

The initial construction process is based on the digitized geometry of the knee model. The point cloud model is the reference model for constructing the initial points, planes, and curves [18, 21]. Given the geometry basis, the surgeon's recommendations for the surgical procedure, like instrument entry directions and knee orientation, were considered. In Fig. 3.1, the elemental planes of brace insertions considering the femur and tibia are defined using axes and planes. These axes can be modified using two constructed (anatomical) points (RGEs), thus providing surgeons more insights into the right insertion direction. They are also considered as parametric points, because they can be modified according to the specific patient anatomy and surgeon recommendations. The parameterization of the axes and points is reflected in the CAD capabilities to transform coordinates through the interface easily. Another great potential is to transfer coordinates data to external files (CVS, MS Excel) in which they can be defined and imported into other computer graphics software. In this case, both options are implemented. Fig. 3.2 presents the guiding cylinders and planes, which are constructed using the RGE axis. They can be used for better preoperational planning because they provide a more visually appealing view of the insertion directions.

The next step is to define RGE points on the ACL outer surface to form an RGE point cloud. Then, spline curves will be created as initial CGEs. The spline curves will be used to create the NURBS patch and SubD models for the ACL outer surface and Brace. The initial points and spline curves are demonstrated in Fig. 3.3a. In Fig. 3.3b, the surface model of the ACL outer surface is presented. It was created using a multi-section surface technical element, three profile curves, and one central guided curve. The Anatomical points cloud model reflects its parameterization. By changing the point(s) coordinates presented in [22], the model can be adapted to the specific patients geometry. The ACL outer surface model is a basis for creating the InternalBrace model. The brace model uses the guiding curve of the ACL surface model as a tangential curve for the surface model construction (Fig. 3.3c). The constructed brace model is presented in the Fig. 3.3b. The model is parameterized using width and height as basic parameters, surface orientation in the starting plane by 30^0, and the guiding curve anatomical points (Fig. 3.3b and Fig. 3.3c that belong to the ACL surface and, consequently, the brace.

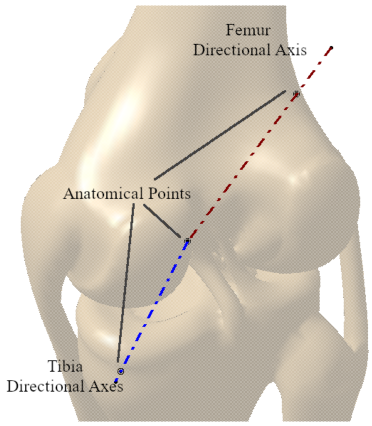


FIG. 3.1: The guiding axes construction with three Anatomical points

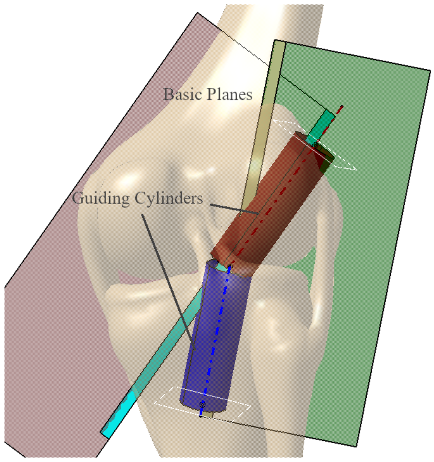


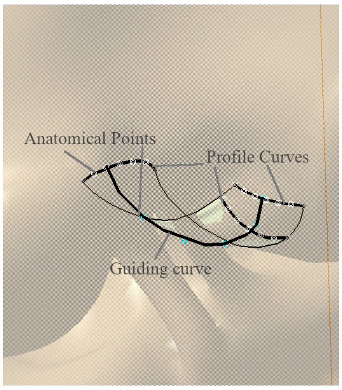
FIG. 3.2: Directional planes and cylinders

A similar procedure was conducted to construct a SubD model. The profile and guided curves were selected similarly, and the model was formed using the NET curves technical feature. The models are presented in Fig. 3.4a (construction process) and Fig. 3.4b (formed SubD models).

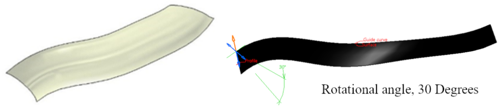
The two created models were compared by using surface continuity and deviation analysis. This analysis is only done to show initial deviations because both surface models can be adjusted by using RGEs (anatomical points) and curves (CGEs). The Max deviation was 0.792 mm (Fig. 3.5a), and in the orthogonal direction max deviation was 0.585 (Fig. 3.5b).

The anatomical points initially defined as RGEs can be used to create any other type of CGEs or surface models. For example, a wireframe or polygonal model can be formed and used adequately. This is especially important when 3D printing is required because it is easy and relatively fast to form a model for printing in plastic or metal. In such cases, the STL (Stereolithography model) model for 3D printing can be created in a matter of minutes by just importing a cloud of points in the 3D Printing software and performing standard operations (transformation, material selection, printing parameters modifications) [7].

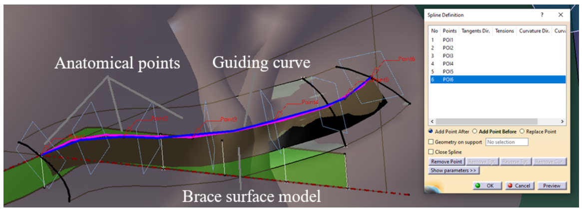
In this case, the SubD ACL, Brace, and knee models were printed to make presentations for the medical trainees (students, practitioners). The printed models are presented in Fig. 3.6b, while 3D geometrical models are presented in Fig. 3.6a. The brace model is scaled by 20% to be visually comparable with other models. The chosen printer was an FDM Bambu Lab X1-Carbon Combo. The printed material was ABS plastics with standard printing parameters (0.1 mm layer thickness, 240^0 C printing temperature). This shows how material properties for the FDM 3D printing process can be added to the geometrical model of human organs and implants.



(a) The RGEs and CGEs definition on the ACL outer surface model

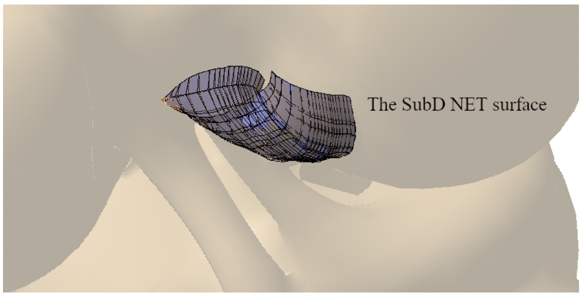


(b) Surface model of the ACL and brace

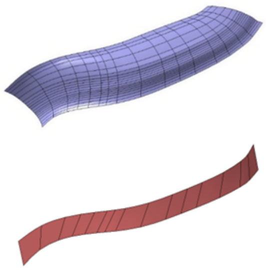


(c) The RGES and CGEs for the brace model

FIG. 3.3: The construction of the ACL and brace surface model



(a) The SubD (NET) ACL surface model construction



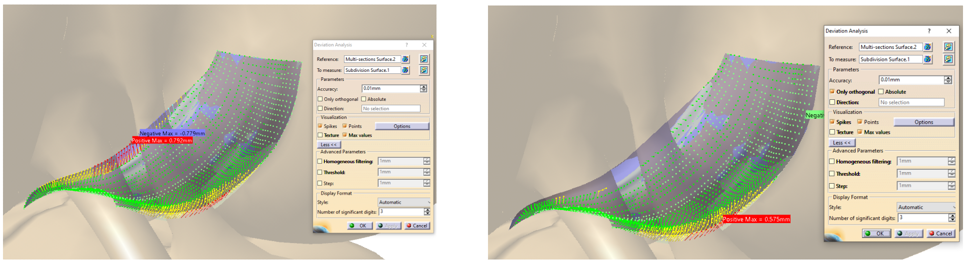
(b) The SubD surface models of the ACL and Brace

FIG. 3.4: The definition of the ACL and InternalBrace SubD models

Considering the created models, it can be concluded that they support the anatomical properties and functional and material requirements of the ACL and brace. The anatomy is reflected in the formed surface models. Functionality is contemplated with the possibility of using the models to simulate the ACL and Brace functions (e.g., teaching), and to reduce the possibilities for the defined complications. Using machine-integrated software, the material model was assigned to the geometrical model in the 3D printing process definition.

3.4. The additional parametric model definition

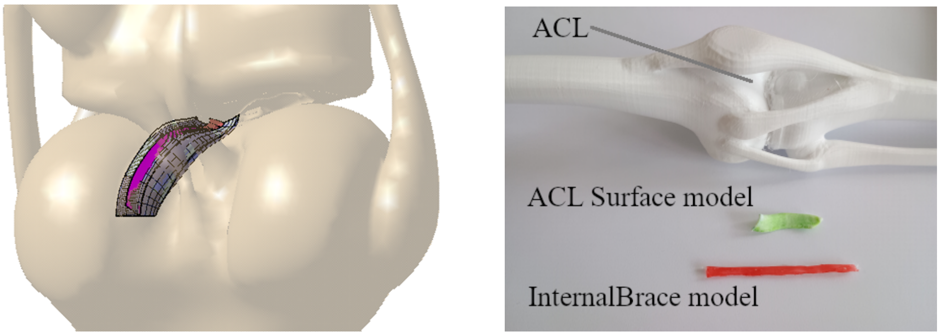
More anatomical (geometrical) points are needed on the ACL NURBS or SubD surface model to create a complete parametric model of its surface. Both models can



(a) The general deviation between NURBS and SubD surfaces

(b) The orthogonal deviation between NURBS and SubD surfaces

FIG. 3.5: The deviation analysis between surface models



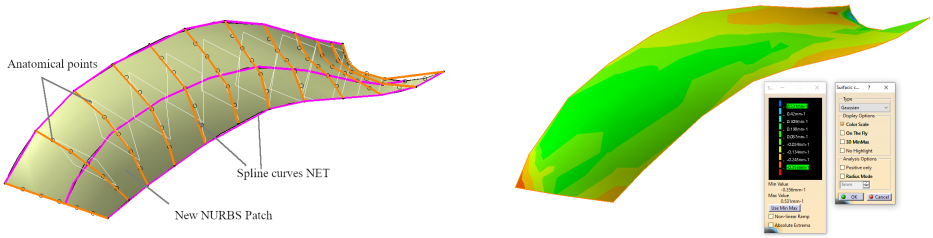
(a) The 3D CAD model of the knee, ACL, and Brace

(b) The printed model of the knee, ACL and Brace

FIG. 3.6: The 3D CAD and printed models of ACL surface and knee

be used for parameterization. Still, based on the previous work, the NURBS surface model was chosen [16, 18, 20] to define anatomical points (RGEs) for the parametric model, presented in Fig. 3.7a. The set of anatomical points forms the Region of Interest (RGI) [19] for the ACL. The net spline curves built over anatomical points are used to create a new NURBS Patch, which is entirely manifold and with satisfactory geometrical continuity with a max deviation of 0.531mm (Fig. 3.7b).

The anatomical points formed in this way are extracted, and an initial matrix of points is created like the one shown in (3.1). This matrix is needed to adapt the ACL surface model to specific medical cases using different tools (CAD software, 3D Printing Software, Mathematical software). The Brace or any other additional model based on ACL geometry can be created by using an ACL parametric/personalized model and its own defined parameters (for the brace: width,



(a) Anatomical points and net curves (b) The Gaussian curvature analysis

Fig. 3.7: The detailed parameterization of the NURBS patch

height, angle).

$$(3.1) P_{i,j} = \begin{bmatrix} P_{1,1} & \dots & P_{1,n} \\ \vdots & \ddots & \vdots \\ P_{m,1} & \dots & P_{m,n} \end{bmatrix} ; m - profile\ direction, n - guides\ direction$$

To modify the surface model, it is enough to manually change the coordinates of each anatomical point in CAD software or by using imported values from external files (ASCII files). In both cases, having point coordinates in adequate form is essential; for example, for CAD manual adaptation, it is enough to change it using its technical features for cloud point adaptation and transformation. Another possible application of anatomical point cloud is to export it to STL (ASCII or binary) and use it as a transfer format for different applications to enable various model adaptations and use.

Future work on the ACL parametric model requires a mathematical description of anatomical point coordinates as functions of morphometric parameters [18–20] and their integration with already created parametric models of the femur and tibia. This task should be part of the following work on the model improvement, and it will enable semi or full-automatic ACL surface adaptation (and Brace consequently) to the specific patient, the same as it is now for the femur and tibia.

4. Conclusion

The reconstruction process of human organ models is very complex. Therefore, this paper presents two complementary methodologies created by the authors of this research for creating Anterior Crucial Ligament (ACL) and Internal Brace models: the Characteristics Product Features (CPF) and the Method of Anatomical Features (MAF).

CPF methodology, combined with the MAF, focuses on the design of 3D geometrical and physical models of human organs and implants. Furthermore, this study demonstrates the enhancement of MAF by adding the CPF method as an MAF sub-process for remodeling. Different ACL and InternalBrace models were formed and presented to confirm methodology improvements. The NURBS patch, SubD, parametric, and physical models of ACL and InternalBrace were created to demonstrate that various requirements could be integrated and used to create valid geometrical and physical models. Also, by using this approach, it is possible to create different types of complex models, not just geometrical, but functional, material [5], and technological of human organs, and apply them in computer-assisted surgery (CAS), thus improving patient treatment and recovery processes.

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