ISSN 2581 – 3781

AJCSE ASIAN JOURNAL OF COMPUTER SCIENCE ENGINEERING

Available Online at www.ajcse.info
Asian Journal of Computer Science Engineering 2021;6(4):60-71

RESEARCH ARTICLE

Computational Dual-system Imaging Processing Methods for Lumbar Spine Specimens with Medical Physics Applications

Francisco Casesnoves

Independent Research Scientist Engineering-Physics-Software; International Association of Advanced Materials, Sweden; Uniscience Global Scientific Member, Wyoming, USA; Harjumaa, Estonia

Received on: 25-10-2021; Revised on: 30-11-2021; Accepted on: 29-12-2021

ABSTRACT

Based on previous studies, a comparative-series of improved imaging-computational for new/different lumbar cadaveric specimens was obtained with two systems—namely Matlab and GNU-Octave. Algorithmic methods for program patterns are improved and developed. Results comprise a biomedical study of each and every lumbar cadaveric specimen with contrasted evaluation for both computational systems. Imaging processing methods for resolution in improved vertebral contrast/facets/positioning, vertebral-anatomical parts separation, visualization of lumbar spines, and different 3D imaging options available, are explained and proven. In Clinical Medical Physics and Computational Anatomical Pathology, these advances associated to improve previous imaging contributions and statistical data are demonstrated. Results show sharply the usage of Matlab and GNU-Octave imaging processing, programming codes/patterns, and computer vision tools. Efficacious utility of these computational-software imaging methods, useful/appropriate for clear/detailed anatomical-clinical analysis, and comparisons among cadaveric specimens are illustrated along an imaging series. The anatomical dissection methods previously published obtain additional procedures/applications in lumbar vertebra study, statistics, and surgical tools manufacturing. Applications on Medical Physics, Biomedical Engineering, and Computational-Forensic Diagnosis are got from this dual cadaveric imaging systematic comparison. Matlab and GNU-Octave software 3D imaging methods utility are explained/extrapolated for other type of usages.

Key words: Computational anatomical dissection, Image processing, Software engineering, Surfactal Programming, Computer aided design, Computer aided manufacturing, Anatomical cadaveric imaging simulations, Biomechanics, Bioengineering, Spinal computational-surgery, Spinal ligaments, Spinal anterior longitudinal ligament

INTRODUCTION AND SPINAL BIOMECHANICS ANALYSIS

A series of previous publications[1-12] in Surfactal computer aided design (CAD) and computer aided manufacturing (CAM) presented 3D imaging methods to obtain biomechanical, clinical medical physics, anatomical systematic study, and forensic analysis of lumbar cadaveric specimens. The anatomy of vertebra differs systematically for every part of spine. The most dissimilar are the cervical ones, while thoracic and lumbar vertebras show more resemblance. Any vertebra can be characterized for a number of anatomical shape peculiarities. These are vertebral body, dimension, pedicles, facets, facet-curvature, ligaments that support it, ligament insertion zone, spinal cord channel size, geometry at different stages of lifetime, or any pathological/non-pathological particular patient sign.[1] Moreover, during lifetime, the vertebra shape and histology experience changes together with the whole spine in general. Lumbar vertebra loads are about 500 N, and this biomechanical factor causes a significant deformation during lifetime. The changes of the intervertebral disks are more considerable as disks support these loads and have a deformable histological structure. Therefore, the bioinformatics study at every life stage can provide database for surgical theatre pre- and post-operative planning and/or instrumentation manufacturing.

Address for correspondence:
Francisco Casesnoves,
E-mail: casesnoves.research.emailbox@gmail.com

The spinal pathology study can obtain valuable data from the analysis of anatomical/physiological changes during average lifetime. Preventive and statistical medicine also gets substantial evidence from this database and CAD imaging analysis. CAD and CAM are widely used, for instance, for design of spinal prostheses, devices, tools, orthopedics apparatus, pediatric orthopedics, and spinal stabilization devices. That is, new prostheses, surgical-theatre tools, spinal screws, stabilization kits, artificial intervertebral disks, grips, etc., CAD, based on anatomical data, is useful/efficacious for accurate affix of spinal prostheses/devices—fitting error and post-surgical complications are then reduced.

This contribution differs from the former studies in objectives and results. That is, the paper aim is focused on computer vision tools and digital imaging processing usage for getting digital database from lumbar cadaveric specimens. Digital anatomical records from the imaging laboratory apparatus, for example, a scanner are important and constitute the first stage for these purposes. However, if they are not conveniently computationally analyzed/software-implemented to set high-quality representations/images with good numerical approximations database is not suitably managed. Figure 1 shows a CAD hyperbolic vertebral body model to set the cadaveric specimen digital data for a geometrical model of a hyperboloid.[10]

Hence, this study proves how computer vision tools and image processing are efficacious to get/extract clinical information from lumbar cadaveric specimens. The characteristics that are studied are mainly lumbar spine specimen shape, vertebra pathology, arthrosis traces/damage, facet curvature and degeneration, vertebra and disk deformation, disk protrusion, pedicles, traces of ALL, ligaments, and other applicable data in clinical medical physics. All these methods are applied with two systems, Matlab and GNU-Octave. In addition, a comparative assessment of these two programming systems functionality is presented.

In summary, this study shows usage/utility of a number of imaging processing and CAD vision tools to examine and extract medical-surgical information from lumbar cadaveric specimens. It is based on program codes, subroutines applications, options best optimization, and programming patterns. Two computational systems for these objectives are applied and contrasted, Matlab and GNU-Octave. Moreover, pre-hypotheses/extrapolated applications for future clinical medical physics and surgical applications are suggested/explained. Results and images, system comparisons, and programming techniques can be considered acceptable both for bioengineering advances and lumbar/general spinal surgery applications.

CLOUD DATA CADAVERIC SPECIMEN MATERIALS

Matlab scanning cloud data

As in previous studies,[3,8-12] a digital scanner apparatus was the experimental method to select numerical data. The laboratory method was obtained the cadaveric specimens cloud data of lumbar spines with the digital scanner, once the anterior part of the specimens was exposed to waves. The CAD surfactal fit was obtained from

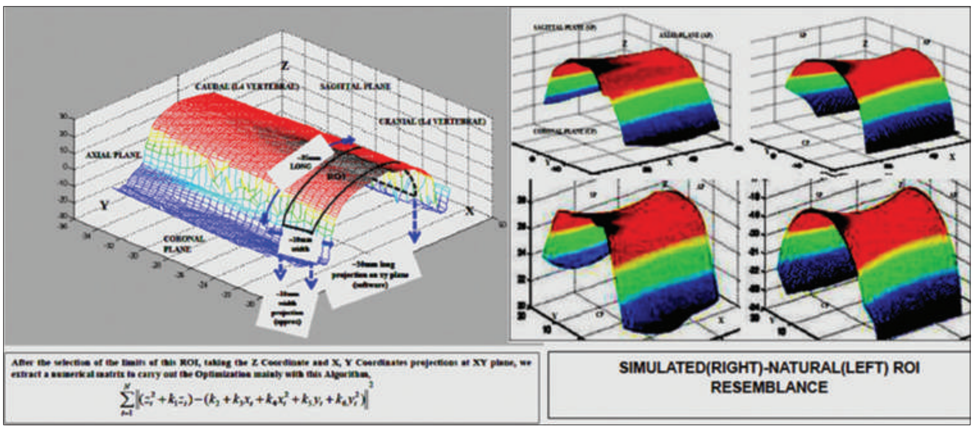

Figure 1: From, a polynomial computer aided design (CAD) model for a region of interest, of the vertebral body of a lumbar spine specimen. The polynomial fit was made with a CAD method taking the digital scanned data from the specimen

different and also previous anterior vertebral body anatomic samples. The cloud data of this experimental samples, as in,[3,8-12] were obtained using high resolution in the 3D Scanner Digitizer (high resolution was $\simeq 10^{-7\,m}$). In most cases, the data obtained of the spine surfaces had $\simeq 10^5$ points for each specimen. For Matlab and GNU-Octave comparative study, the specimen 1 has about 16350 3D points. The specimen 2 has approximately 16300 3D cloud points.

With interpolation algebraic methods, cloud point number is condensed from $\simeq 10^5$ to $\simeq 10^4$ to increase the visualization program image-set and speed. The reduction of point's algebraic method was performed by interpolation software, taking approximate middle points among intervals. In previous contributions, extent developments of the specimens for computational programs were carried out.[3-5,8-12] The objective was to interpolate the cloud data to optimize the imaging processing tools usage, and not all the specimens have the same interpolation parameters, since the 3D cloud data number differs for everyone.

GNU-octave scanning cloud data

For computational comparisons, a new specimen was added to contrast imaging vision processing between GNU-Octave and Freemat. This specimen was studied in Matlab in previous contributions.[3-8] Number of digital cloud 3D data is 14055. Cloud point number is reduced from $\simeq 10^5$ to $\simeq 10^4$ to increase the visualization program speed. This cloud data specimen was prepared exclusively to prove the functionality of GNU-Octave 3D imaging process. The previous sub-section data for specimens 1 and 2 were also programmed in GNU-Octave.

MATHEMATICAL METHODS AND IMAGING SOFTWARE

Both in Matlab and GNU-Octave, image processing, and computer vision tools were the principal implement to obtain the images and use the Matlab camera settings. For Matlab, the programming method was based on both classical 3D tools, and camera settings—, appropriate subroutines and a group of commands/sentences to set spinal 3D images accurately. For GNU-Octave, the camera images similar to Matlab require laborious task. Matlab and GNU-Octave programming techniques are based on previous contributions and literature.[2,4-16] In Matlab, the following imaging processing settings were used: Zoom, rolling, projections along axes, orbit, tilt, moving (horizontal, vertical, forward, backwards), definition of principal axes, imaging contrast and tiles size. In GNU-Octave, rotation, pan, text box, toggle, zoom in-out, and commands/options for color, tiles, image definition, etc. Table 1 shows a comparative set of Matlab and GNU-Octave reference-standard algorithms, functions, tools, and applications for image processing, analysis, visualization, and algorithm developments.

For Matlab, the average running time for a cadaveric image was 2–10 s. For GNU-Octave, it is at least 15 s, depending of the amount of 3D subroutine options. In Matlab, the image tools time

Table 1: Computer vision tools used for images. Upper, Matlab imaging processing methods. Lower, GNU-Octave imaging tools

MATLAB computational image and vision techniques	
Vertebral length	To be determined by number of cloud data and tiles size
Lumbar spine positioning	All projections along axes, orbit, tilt, moving (horizontal, vertical, forward, backward)
Vertebral facets	Projections along axes, orbit, tilt, moving (horizontal, vertical, forward, backward)
Disks	Projections along axes, orbit, tilt, moving (horizontal, vertical, forward, backward)
Arthrosis osteopathy degeneration signs	Contrast, tilt, zoom, very easy use and fast
ALL	Contrast, tilt, zoom, traces visualized along some vertebral specimens
GNU-octave computational image and vision techniques	
Vertebral length	To be determined by number of cloud data and tiles size, can be guessed from axes information
Lumbar spine positioning	All projections along axes, rotation is easy, no orbit and tilt, moving (horizontal, vertical, forward, backward),
Vertebral facets	projections along axes, there is no orbit and tilt, moving (horizontal, vertical, forward, backward)
Disks	No camera projections along axes, no orbit or tilt, moving (horizontal, vertical, forward, backward)
Arthrosis osteopathy degeneration signs	Contrast, zoom is possible but more difficult than Matlab. It is clearly seen any pathological sign, as image is very clear.
ALL	Traces can be visualized along some vertebral specimens
Image definition and text insertion	Image can be considered very good, and Text can be inserted but text boxes are difficult and complicated to set
Pan tool	It works fast and provides with facility to displace the image along axes

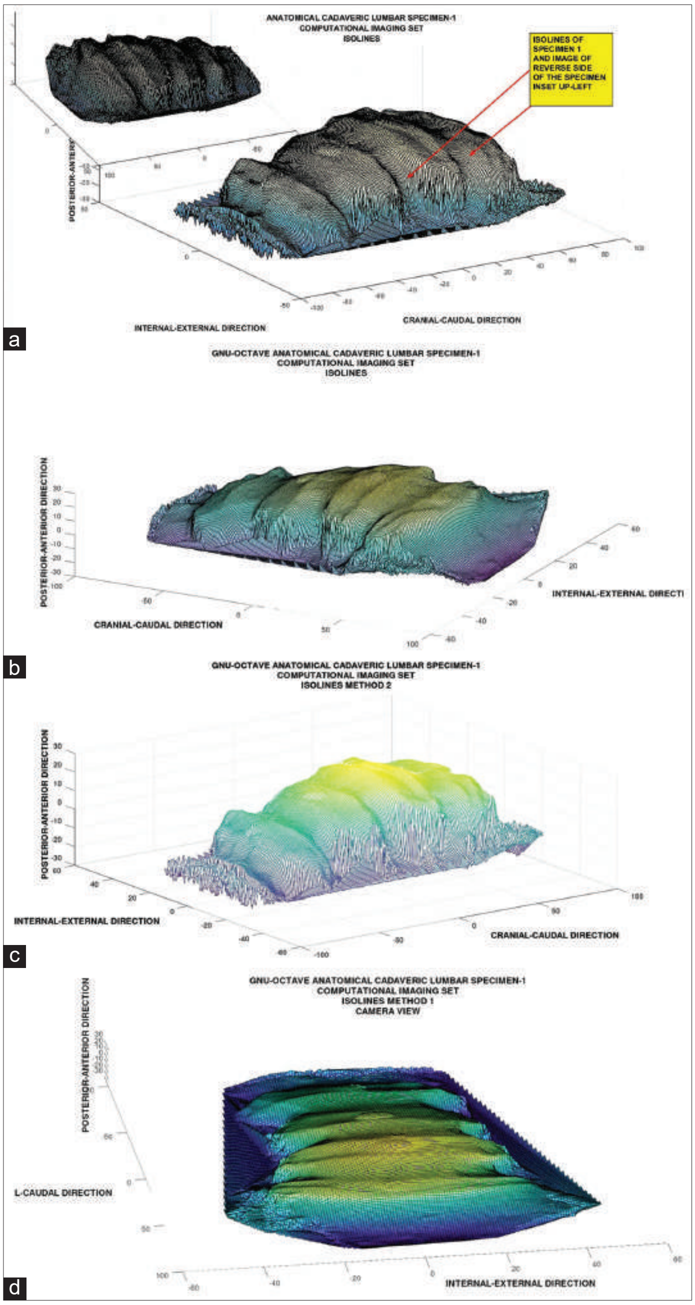

Figure 2: (a) Matlab-Method-1.-L5 facet lateral-right image processing separation in specimen 1. Facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. The complete L5 lateral-right facet is shown. Pictured inset, left-up, the lateral-left image. Conservation in general is good with one arthrosis nodule. Image color, definition, and contrast were got using vision tools in Matlab and proper sentences in program. The protrusion rounded-nodes at disks have no significance, since are the traces of experimental surgical insertion tools for other studies. (b) GNU-Octave-Method-1.-L5 facet lateral-right image processing separation in specimen 1. Facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in GNU-Octave program. The complete L5 lateral-right facet is shown with signs of facet degeneration. Conservation in general is good with one arthrosis nodule. Image color, definition, and contrast were got by using vision tools in Matlab and proper sentences in program. The protrusion rounded-nodes at disks have no significance, since are the traces of experimental surgical insertion tools for other studies. (c) GNU-Octave-Method-2.-L5 facet lateral-right image processing separation in specimen 1 with Method 2 subroutine. Image is also good and isolines are well defined. Facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in GNU-Octave program. The complete L5 lateral-right facet is shown. Conservation in general is good with one arthrosis nodule. Image color, definition, and contrast were got using vision tools in Matlab and proper sentences in program. (d) Matlab-Method-1-Camera.-L5 facet lateral-right camera-image processing separation in specimen 1 with Method 1 subroutine. It is necessary to vary contrast and brightness to obtain a similar to Matlab camera image that takes at least 5 min. Image is also good and isolines are well defined. Facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in GNU-Octave program. The complete L5 lateral-right facet is shown. Conservation in general is good with one arthrosis nodule. Image color, definition, and contrast were got using vision tools in Matlab and proper sentences in program

Table 2: Imaging results for specimen 1 in both systems

MATLAB Computational image processing results specimen 1	
Length	Standard
Vertebral bodies, facets	Degenerated, asymmetry, concavity and convexity deformed
Disks	Not significantly herniated but deformed
Pedicles	Can be something observed at L5
Arthrosis osteopathy degeneration	Significant and affecting to all vertebras
Geometrical distribution	Arthrosis changes are non-symmetrically distributed as it is usual in that degenerative-disease
Transversal processes	Cannot be observed
ALL and PLL	Traces can be visualized, PLL (posterior longitudinal ligament cannot) be visualized
GNU-octave computational image processing results specimen 1	
Length	Standard, well defined
Vertebral bodies, facets	Degenerated, asymmetry, concavity and convexity deformed, but more difficult to be set with GNU-Octave
Disks	Not significantly herniated but deformed
Pedicles	Cannot be observed at L5
Arthrosis osteopathy degeneration	Significant and affecting to all vertebras, seen in camera image
Geometrical distribution	Arthrosis changes are non-symmetrically distributed as it is usual in that degenerative-disease
Transversal processes	Cannot be observed
ALL and PLL	Traces can be visualized, PLL (posterior longitudinal ligament cannot) be visualized

to start to work varies significantly. If a text box is inserted into image, it takes at least 15 s. A cursor numerical data extraction takes 5 s. In GNU-Octave, the image tools time to start to work was about 10–20 s. For Matlab, the positioning change speed of camera was about 1 s. The division of numerical intervals for tiles in complete lumbar specimen image was selected about 0.5 for optimal visualization and not long running time. In GNU-Octave, similar images to Matlab camera can be done, but it takes at least 15–20 s.

MATLAB AND GNU-OCTAVE COMPARATIVE RESULTS

The findings obtained by imaging software are presented in a series of computer vision pictures, Figures 1-8. The compared anatomical-clinical details of facets, vertebra sizes and body, pathological signs, ligaments, length, and other are obtained along the images. Tables 2 and 3 show the imaging results summary. Figure 8 presents an special specimen form[3] that was implemented for imaging processing patterns. That specimen is specially longer and shows a sharp protrusion of all disks [Figures 9-11].

Table 3: Imaging results for specimen 2 in both systems. One previous studies[3,3.1] specimen is also analyzed

MATLAB computational image processing specimen 2	
Length	smaller than previous specimens
Vertebral bodies, facets	Concavity and convexity deformed, holes
Disks	Herniated some of them
Pedicles	Can be something observed at L5
Arthrosis osteopathy degeneration	Significant and affecting to most vertebras
Geometrical distribution	Arthrosis changes are non-symmetrically distributed as it is usual in that degenerative-disease
Transversal processes	Cannot be observed
ALL and PLL	Traces can be visualized, PLL (posterior longitudinal ligament cannot) be visualized
GNU-octave computational	image processing results specimen 2
Length	Shorter but well defined
Vertebral bodies, facets	Degenerated, asymmetry, concavity and convexity deformed, but more difficult to be set with GNU-Octave
Disks	Significantly herniated and clearly deformed
Pedicles	Cannot be observed at L5
Arthrosis osteopathy degeneration	Significant and affecting to all vertebras, seen in camera image
Geometrical distribution	Arthrosis changes are non-symmetrically distributed as it is usual in that degenerative-disease
Transversal processes	Cannot be observed
ALL and PLL	Traces can be visualized, PLL (posterior longitudinal ligament cannot) be visualized
Previous study additional specimen Figure 10	This specimen from previous studies was set-programmed in GNU-Octave to show the differences in tissue and ALL traces. It was obtained also with contour option and two methods.

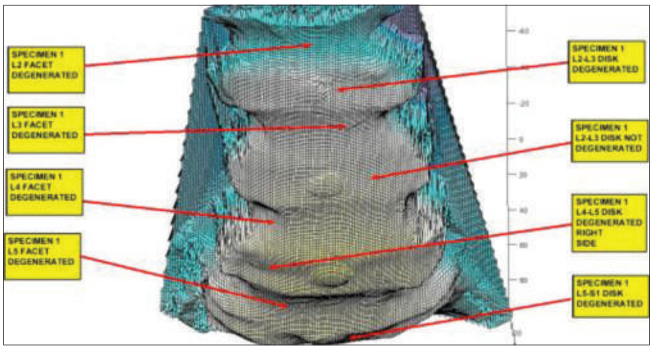

Figure 3: Matlab-Camera. Complete cranial-caudal image of specimen 1. Image was set with processing tools for showing better L2 facet. All facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. The complete L5 facet is shown partially. Image color, definition, and contrast were got using vision tools and proper sentences in program

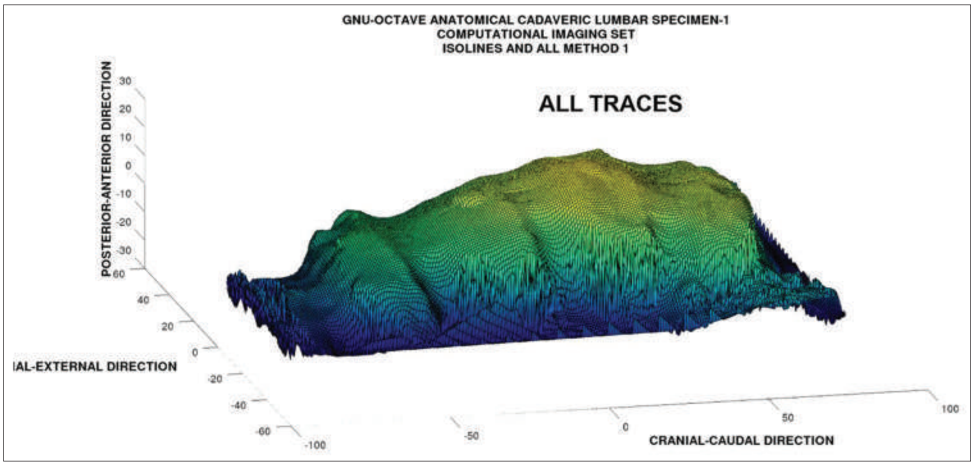

Figure 4: GNU-Octave-Method-1.-Complete cranial-caudal image of specimen 1, set to show the ALL traces at middle specimen. Image was set with GNU-Octave processing tools for showing better the facets. All facet imaging-visualization was optimized setting contrast and the tiles division and brightness-color appropriate numerical data in program. ALL traces can be also identified when the isolines lose definition. That means that the surface-variability of the non-smooth-surface ligament histological structure causes loss of isolines definition

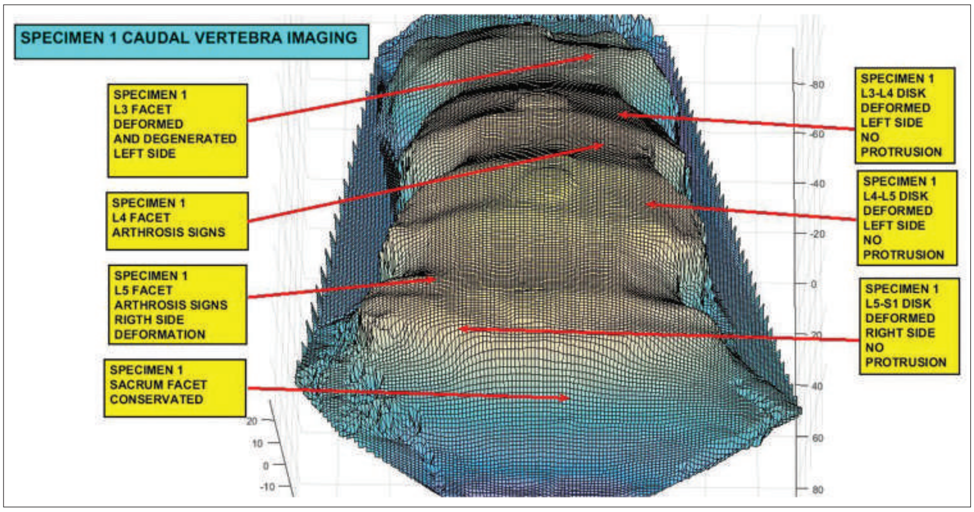

Figure 5: Matlab-Camera.-Complete cranial-caudal image of specimen 1, but tilted to show L5 and Sacrum zones. Image was set with processing tools for showing better L5 facet. All facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. The complete L5 facet is shown in first plane. Image color, definition, and color-contrast were got using vision tools and proper sentences in program

CLINICAL MEDICAL PHYSICS AND BIOENGINEERING APPLICATIONS

Table 4 shows a brief of applications from.[3,8-17] Applications can be clinical and for research in general. Clinical group ones are mainly for spinal surgery. These are from surgical operation tools manufacturing till implants, artificial disks, screws, stabilizers, pediatric orthopedics, intervertebral disc degenerative process diagnosis, bone structure degeneration-form, etc.

Research-theoretical utility is related to all computational software and database for CAM and/or CAD objectives. These could be implant-materials optimization, osseointegration optimization, any prostheses, implant, surgical-theatre conformal apparatus, or orthopedic stabilizers. Database-statistical CAD software for diagnosis-study of spinal pathologies—for example, incidence/prevalence of pediatric and youngsters spinal diseases evolution, professional diseases, elderly statistics for spinal diseases prevalence/incidence, or professional-risk of spinal damage. The CAM design of interfaces is essential. Interfaces of stabilizers, surgical tools, implants, prostheses and orthopedic apparatus have to fit as much optimal as possible. There are several types of clamps, grips and screws, namely, three-point shear clamp, lock screw (with end-on and tangential parts), circumferential grips,

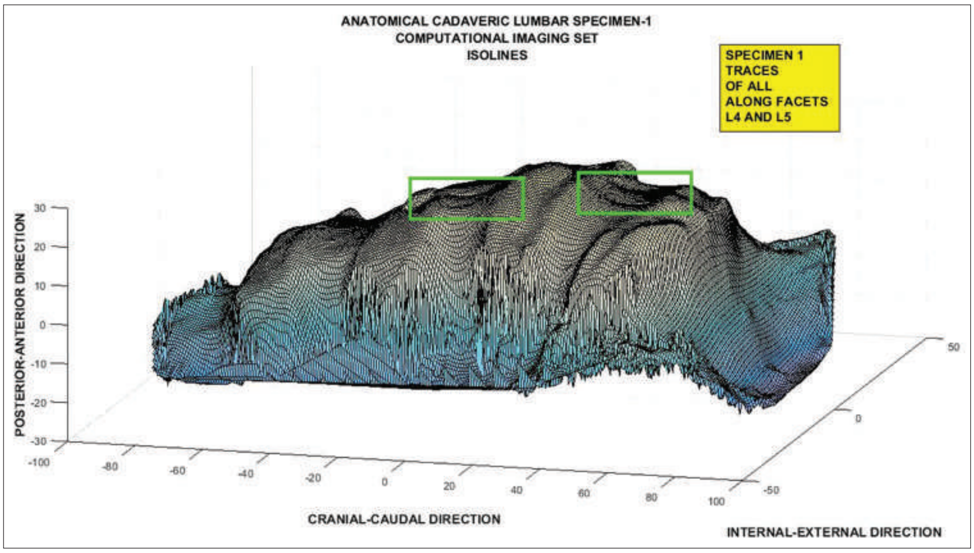

Figure 6: Matlab-Method-1.-Complete specimen 1 lateral-right imaging processing set. It can be compared to Figure 4-GNU-Octave-Method-1. The separation of vertebras in this specimen 1 was got sharp with computer vision tools. Isolines are clear. ALL are marked inset. Facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. The state of conservation of facets-vertebras and disks can be observed. L5 is well preserved, but L4 facet not so well. Color, definition, and contrast were got using vision tools and proper sentences in the program

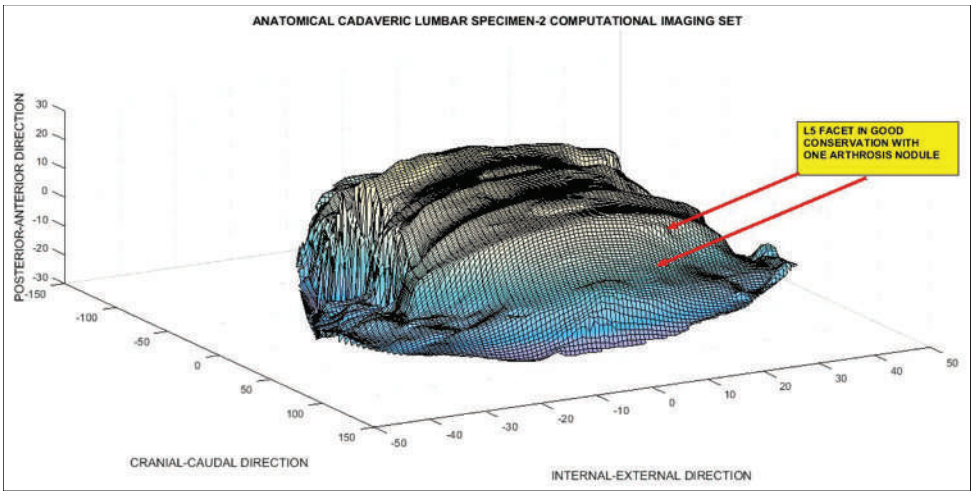

Figure 7: Matlab-Method-1.-L5 facet image processing separation in specimen 2. Facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. The complete L5 anterior facet is shown in first plane. Conservation is good with one arthrosis nodule. Image color, rotation, definition, and contrast were got using vision tools and proper sentences in program

constrained bolt–plate, constrained screw–plate, semiconstrained screw–plate, semiconstrained component–rod, component–component Interfaces, and new recently-designed others.

Optimal interface-precision and bonding is indispensable. This property avoids complications, post-operation complications, locking mechanisms failures, malfunctionality, breaks, corrosion and tribocorrosion of interfaces, friction problems, erosion, abrasion, wear of materials, histocompatibility inmunological reactions, post-operative rehabilitation and pain, and a wide of unpredictable post-surgical complication chances. Deformity prevention and correction in the specialization of pediatric surgery CAM is more complicated in general than the adult's one. The children organism and constitution is in dynamic-growing continuous evolution, and the physical activity of a child is higher than the adult in general. Computational Biomechanics and computational dissection CAD and CAM design constitutes an useful tool to resolve all these pediatric biomedical pathologies. Statistical imaging database for pediatric bones is usually

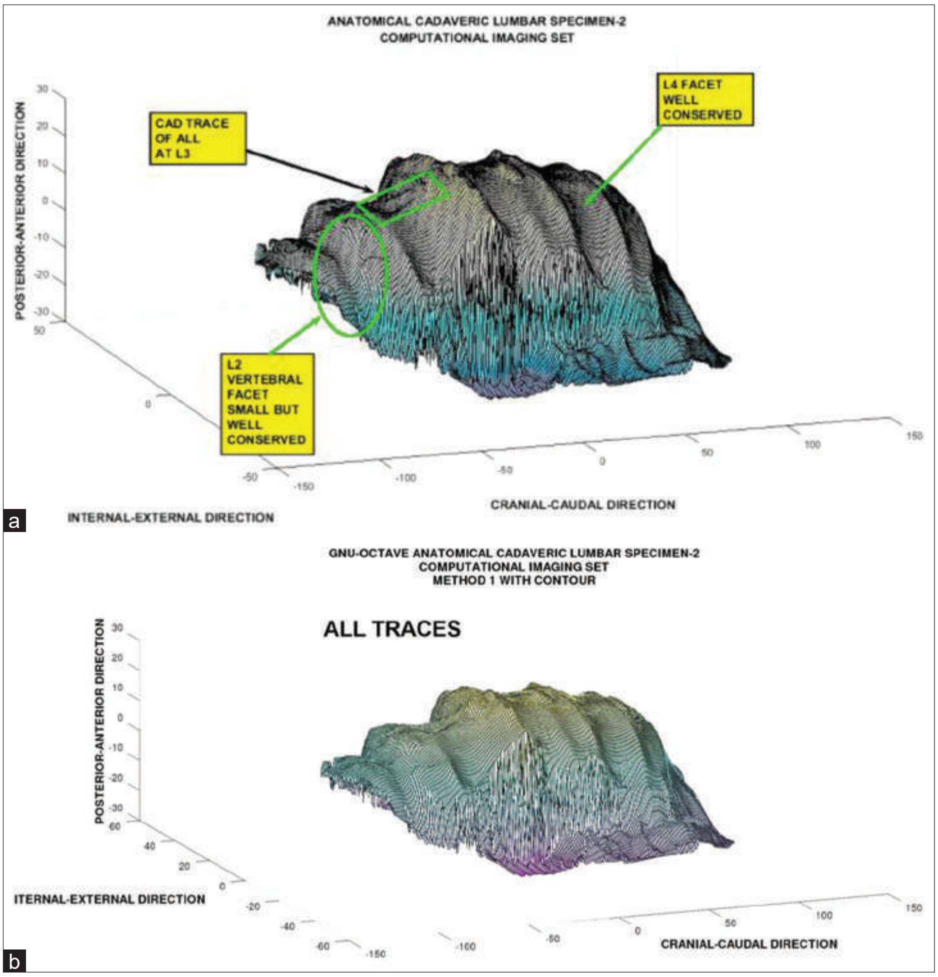

Figure 8: (a) Matlab-Method-1.-L2 facet image processing separation in specimen 2. Facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. The complete L3 anterior facet is shown. The lateral L4 facet is marked. Conservation is good with one arthrosis nodule. Image color, definition, and contrast were got using vision tools and proper sentences in program. Specimen 2 is shorten than specimen 1. (b) GNU-Octave-Method-1.-L2 facet image processing separation in specimen 2. Facet imaging-visualization was optimized setting the contrast tiles division and brightness-color appropriate numerical data in program. ALL traces can be easily identified. The complete L3 anterior facet is shown. The lateral L4 facet is marked. Conservation is good with one arthrosis nodule. Image color, definition, and contrast were got using contrast and proper sentences in program. Contour lines cannot be seen because the contrast was increased. Specimen 2 is shorten than specimen 1

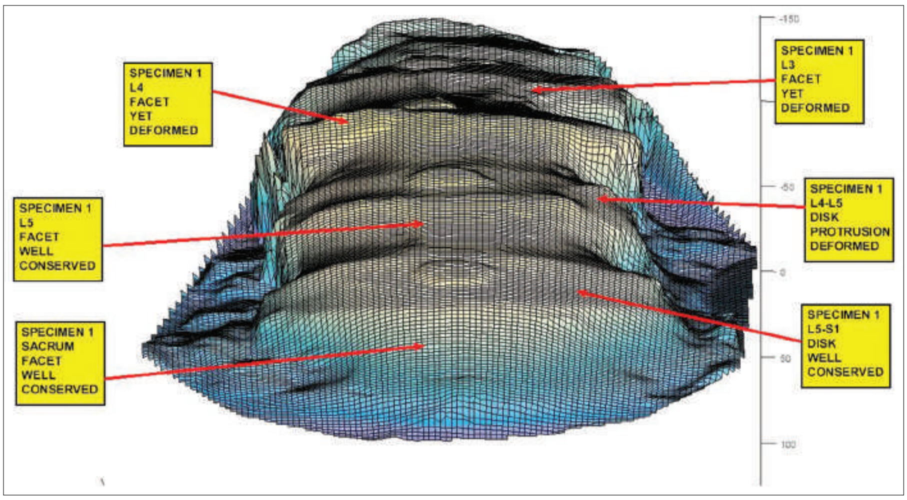

Figure 9: Matlab-camera.- Complete cranial-caudal image of specimen 1, but tilted to show L5 and Sacrum zones. Image was set with processing tools for showing better L5 facet. L4 is deformed. All facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. Image color, definition, and contrast were got using vision tools and proper sentences in program. Error, in image text it should be written specimen 2

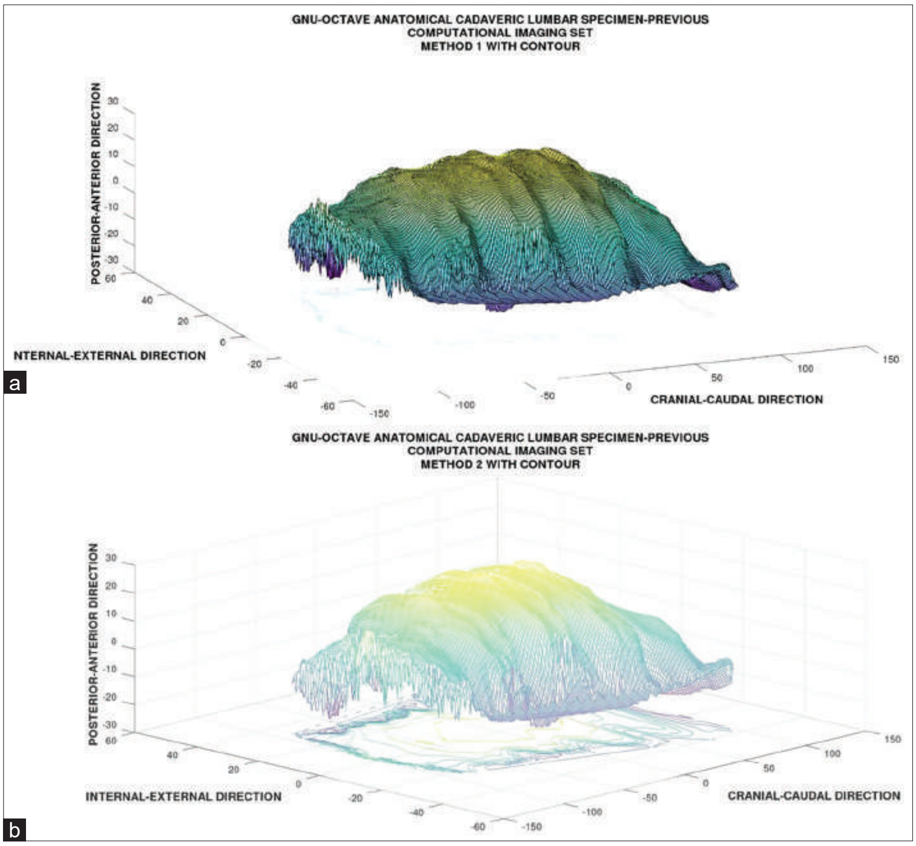

Figure 10: (a) GNU-Octave-Method-1.-Complete cranial-caudal image of specimen from previous publications[3,3.1] set to show the ALL traces at middle specimen. Image was set with GNU-Octave processing tools for showing better the facets. The isolines are not very clearly defined at the middle facets because there is residual tissue in specimen sample. All facet imaging-visualization was optimized setting contrast and the tiles division and brightness-color appropriate numerical data in program. ALL traces can be also identified when the isolines lose definition. Contour lines cannot be seen since contrast was increased. That means that the surface-variability of the non-smooth-surface ligament histological structure causes loss of isolines definition. (b) GNU-Octave-Method-2.-Complete cranial-caudal image of specimen from previous publications[3,3.1] set to show the ALL traces at middle specimen. Image was set with GNU-Octave processing tools for showing better the facets. The isolines are not very clearly defined at the middle facets because there is residual tissue in specimen sample. Yellow zone corresponds to ALL and surrounding tissue adhered. Contour lines can be seen clearly. All facet imaging-visualization was optimized setting contrast and the tiles division and brightness-color appropriate numerical data in program. ALL traces can be also identified when the isolines lose definition. That means that the surface-variability of the non-smooth-surface ligament histological structure causes loss of isolines definition

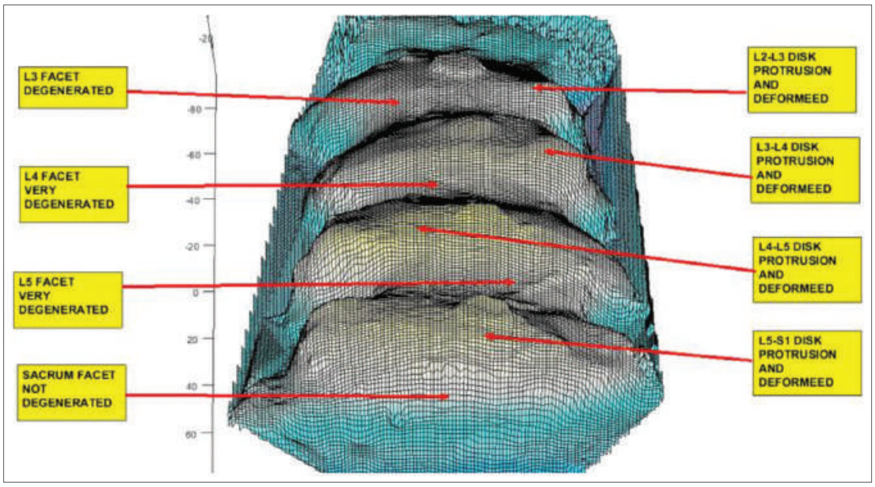

Figure 11: Matlab-camera.- Complete cranial-caudal image of specimen 1 from,[3.1] but tilted to show L4-L5 and Sacrum zones. Image was set with processing tools for showing better all vertebra disks protrusions. L5 is deformed, L4 degenerated. All facet imaging-visualization was optimized setting the tiles division and brightness-color appropriate numerical data in program. Image color, definition, and contrast were got using vision tools and proper sentences in program. This specimen from[3.1] is particularly long and anatomically interesting

Table 4: Resume of biomedical and medical physics applications. Improved from[3,8-19]

Computational dissection medical physics applications	
Spinal surgical pathology field	**Applications**
Bone quality	Can be determined approximately with these methods
Spinal cad	All tools and prostheses optimal design
Spinal cam	All tools and prostheses optimal manufacturing design
Osseointegration optimization	Direct bonding of bone to an implant improvements.
Spine tools and apparatus	Spinal instrumentation, implants and deformity correction prostheses, implant-bone optimal interfaces instrumentation, all kind of screws, rods, grips, distractors, screw-insertion-angle optimization for a wide range of implants
Implant materials optimization	Study with CAD-CAM suitability of implant materials manufacturing
Prostheses	All types of implants, artificial disks, clamps, stabilizers, etc.,
Prevent Structural injury	Optimization of interfaces and implant structure can prevent structural injuries
Surgical tools And prostheses Interfaces	This is a practical/important application
Orthopedics	Spondylolisthesis, scoliosis, and all other types of deformations orthopedics apparatus
Instrumental forces applications design	Optimization of surgical tools, implants, and prostheses to apply biomechanical and surgeon forces with precision and without damage/injury risks
Pre-operation	Pre-operation computational simulations/optimization, pre-operation design of implants or necessary new tools at theatre
Post-operation	Complications prevention, post-operation tracking, imaging post-operation computational checking, design of necessary additional post-operation implants
Rehabilitation	Post-surgery orthopedics rehabilitation for motion preservation apparatus, prostheses, electric-mechanical implants
Spine deformations	All types of spinal tools for correction or balance
Preventive medicine	Statistics for prevention of incidence/prevalence of spinal diseases, statistic models for disease evolution
Surgical theatre work	Optimization of all types of tools functionality, interfaces, resistance, corrosion protection, instrumentation ductility and/or fatigue
Pediatric spinal surgery	Deformation, stabilization, correction prostheses, spinal pediatry instrumentation in general
Pediatric orthopedics	Pediatrics stabilization orthopedics

more difficult to be obtained. Results of this study contribute to this research/clinical field.

DISCUSSION AND CONCLUSION

In general, the comparative study has shown the imaging processing different methods with two systems. The objective is to obtain useful clinical and biomedical database from lumbar spine vertebral specimens. Therefore, the results of the paper have two main strands. The first comprises all the clinical and anatomical information that can be got from the CAD images. The second is the programming software improvements that are developed/compared with Matlab and GNU-Octave 3D imaging subroutines and processing tools, Figures 9-11.

The biomedical information that can be guessed for the 3D imaging results is extent. Among them, general lumbar spine diagnosis/functionality, determination of curvatures, arthrosis degeneration, signs, reumathological diseases signs, osteophites, facet smoothness, concavities geometrical data, angles of curvature, size of surfaces, and bone-degeneration/deformation of vertebras. The pathological signs of facets and disks, such as degeneration, asymmetry of facets and body shapes, or disk herniation constitute useful imaging data. Specially, given the prevalence/incidence of surgical intervertebral disk pathology, the state diagnosis of the lumbar disks is important. Just to remind that the biomechanical loads at lumbar spine are the statistically highest—in magnitude order of at least 500 N.[13-19]

As a whole, Matlab shows better facilities for 3D imaging implementation/usage. However, the differences with GNU-Octave are not excessive. All this assessment was presented in Sections 3–4. Both GNU-Octave and Matlab offer two types of 3D imaging subroutines with a large number of additional programming options for image contrast, tiles size, color choices, brightness, etc. However, the usage of all of these takes more running time in GNU-Octave than in Matlab. The 3D cloud data of the vertebras offers a number of research possibilities for data/imaging extraction. This yields to a number Medical Physics and Biomedical applications for CAM constitute the principal applications.

These properties measurement are suitable for new prostheses, intervertebral disk database, spinal screws, stabilization kits, artificial intervertebral disks, grips, etc. Also for precise-mesh surgical tools manufacturing, spinal stabilization, artificial implants/prostheses, orthopedic apparatus/instruments, surgical robotics and computational preparation/design of surgical intervention.[1-12] All these results are suitable for clinical medical physics and biomedical study, and surgical industry.

In brief, the research has proven the utility of imaging processing and computer vision techniques to obtain digital database from lumbar spine vertebral specimens. The biomedical and clinical medical physics applications are efficacious and wide. The software engineering for 3D imaging processing constitutes an advance for lumbar spine specimen CAD and CAM.

SCIENTIFIC ETHICS STANDARDS

This contribution is based on Graphical Visualization-Optimization methods for cadaveric specimens of lumbar spine with software improved from previous articles. Graphical-Optimization Methods were created by Dr Francisco Casesnoves on December 2016. Forensic Robotics Integrated Systems engineering-concepts were developed by Casesnoves in July 2020. The new laboratory specimens are different from previous publications. The images of previous contributions,[3] are set to compare Matlab camera images with GNU-Octave vision processing methods. Table 4 is improved/developed from previous publications clearer.[3] The picture-illustration processing and computer vision tools programs and special software to obtain new images of specimens, positioning, panoramic vision, enhancement of selected vertebras, or imaging tiles optimization was originally developed by author. This comparative-advanced article has a few previous paper information, whose inclusion is essential to make the contribution understandable. This study was carried out, and their contents are done according to the European Union Technology and Science Ethics. Reference, "European Textbook on Ethics in Research." European Commission, Directorate-General for Research. Unit L3. Governance and Ethics. European Research Area. Science and Society. EUR 24452 EN. Also based on The European Code of Conduct for Research Integrity. Revised Edition. ALLEA. 2017. Revised Edition. ALLEA. The applications section has some mandatory words from previous contributions. This research was completely done by the author, the software, calculations, images, mathematical propositions and statements, reference citations, and text is original for the author. When a mathematical statement, proposition or theorem is presented, demonstration is always included. The article is exclusively scientific, without any commercial, institutional, academic, religious, religious-similar, political, or economic influence. When anything is taken from a source or previous contribution, it is adequately recognized.[21,22]

AUTHOR'S BIOGRAPHY

Dr. Francisco Casesnoves earned the Engineering and Natural Sciences PhD by Tallinn University of Technology (started thesis in 2016, thesis defence/PhD earned in December 2018, official graduate Diploma 2019), and works in computational-engineering/physics. Dr. Casesnoves currently is independent research scientist. He earned MSc-BSc, Physics/Applied-Mathematics (Public Eastern-Finland-University, MSc Thesis in Radiotherapy Treatment Planning Optimization, which was developed after graduation in a series of Radiation Therapy publications [2007-present]), Graduate-with-MPhil, in Medicine and Surgery (Public Madrid University Medicine School). Casesnoves studied always in public-educational institutions. Casesnoves resigned definitely to his original nationality in 2020 for ideological, and ethical-professional reasons, and does not belong to Spain Kingdom anymore. His constant service to International Scientific Community and Estonian technological progress (2016-present) commenced in 1985 with publications in Medical Physics, with further specialization in optimization methods in 1997 at Finland—at the moment approximately 100 recognized publications with approximately 62 DOI papers. His main branch is Computational-mathematical Nonlinear/Inverse Methods Optimization. Casesnoves best-achievements are the Numerical Reuleaux Method in dynamics and nonlinear-optimization (books 2019–2020), the Graphical and Interior Optimization Methods (2016-8), the new Computational Dissection-Anatomical Method, (2020) and invention of Forensic Robotics (2020–2021). Dr Casesnoves scientific service since 2016 to the Free and Independent Republic of Estonia for technological development (and also at Riga technical University, Power Electrical and Electronics Department) is about 30 physics-engineering articles, two books series, and 1 industrial radiotherapy project associated to Europe Union EIT Health Program (Tartu University, 2017).

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