

Three-Dimensional Computed Tomography Reconstruction: other Tool to Teach in the Veterinary Colleges

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Summary— The purpose of this paper was to use three-dimensional computed tomographic reconstruction as another tool to teach in the veterinary colleges. 2-millimeters thick transverse images of two foals and one dog were obtained. Images provided excellent detail of relevant anatomic structures and detailed information regarding the extent of disease and accurate discrimination of neoplastic versus non-neoplastic diseases. Tridimensional reconstruction can be a valuable diagnostic aid for clinical evaluation of several disturbances and could be used as a tool for teaching anatomy in veterinary schools.

Key words— Computed tomography, 3-D reconstruction, anatomy

I. INTRODUCTION

In recent years plastination has begun to revolutionize the way in which human and veterinary gross anatomy can be presented to students. Plastinated specimens have also been used as resources to improve the quality of teaching and learning of anatomy and clinical diseases. Many sources describe different options to enhance anatomical learning by students through increased motivation, including the use of live animals; the use of problem-based learning (PBL) and virtual-reality surgical simulators, as well as the modern imaging techniques such as ultrasound, magnetic resonance imaging or computed tomography.

Computed tomography (CT) is an image diagnostic technique that utilizes x-rays as its imaging source. The transmitted radiation is calculated by a detector connected to a computer for analysis using a mathematic algorithm, which reconstructs the information as a tomographic image [1]. When compared

with conventional radiography, the digital image format of CT results in improved tissue contrast. Manipulation of the grey scale allows optimal visualization of all tissues within the slice.

The contribution of CT to anatomical and clinical knowledge has been very limited due to the high cost and the lack of suitable design of this equipment for adult animals. The CT scanners used in veterinary medicine are designed to use in human patients; therefore, this type of machines are only suitable for small animals due to size constraints of the CT gantry and scanning table. Due to all these limitations most of the studies on large animal such as the horse are focused on technical procedures [2], head diseases [3-5], and distal extremities [6-7].

The recent advances and refinements in Computed Tomography (CT) technology involve the application of computer software for the generation of three-dimensional (3D) construction of an area of anatomic interest. This technique requires multiple thin section images and advantages of this procedure are that anatomical detail is improved and bony structures are imaged with different degrees of rotation [8]. Computed tomography reconstruction has been applied previously in small animals for assessment of canine cervical and lumbar spine [9], as well as in the anatomy of the immature California sea lion head [10], or sinonasal, and orbital diseases [11]. In addition, anatomical features, fractures and deformations of the skull may be imaged with the use of three-dimensional (3D)-rendering techniques[12]. Therefore, this study reports different examples of the use of 3D computed tomographic reconstruction and how this technique may contribute to the knowledge of the normal anatomical relations and the better understanding of several diseases that can cause specific disturbances in animals.

II. MATERIAL AND METHODS

To perform this study, CT images were obtained at the Veterinary Hospital of the University of Cornell (USA), from two clinically normal, neonatal 5 days old Quarter horse foals and an eleven years old male mixed breed dog that in the physical examination showed a mass formation located at the orbital region. The dog presented neurological signs probably due to direct invasion of the cranial vault by this mass formation. Animals were preanesthetized with xylazine at 0.5 mg/kg, IV (Rompun[®], Bayer HealthCare AG, Germany). The anesthesia was induced with a bolus of propofol at 2.0-2.5 mg/kg, IV (Diprivan[®], AstraZeneca U.K.) administered through a jugular catheter. The animals were intubated with a cuffed endotracheal tube to maintain an airway. Anesthetized animals were placed in sternal recumbence on the scanning table and monitored by counting respiratory and pulse rates. A serie of 2-mm thick transverse images from the occipital condyles to the fifth cervical vertebra of the foals and from the entire head of the dog were obtained using fourth generation CT equipment (General Electric Medical System, Milwaukee, WI). The parameters used for CT imaging were 120 kVp, 560 mAs. To better evaluate the cervical spine junction in the foals, a three-dimensional (3-D) reconstruction was performed with special emphasis on atlantoaxial and atlantooccipital areas. In relation to the dog, the 3-D reconstruction was performed with special emphasis on the orbital region, as well as the frontal and parietal bones.

III. RESULTS AND DISCUSSION

Computed tomography reconstruction of the cervical spine foal enabled visualisation of all parts of the vertebrae, including articulations between vertebrae. The most representative sections were selected in order to show detailed anatomy of cervical spine structures. In a lateral view of the 3D reconstructed CT image of the cervical spine, the atlas or first cervical vertebra with its atypical structure was seen. It articulated with the skull cranially, showing modified articular processes also called cranial articular foveae, which articulate with the occipital condyles of the skull to form the atlanto-occipital joint. The transverse foramina located just lateral to the lateral masses were also seen. The axis, or second cervical vertebra showed an elongated and modified spinous process as its most prominent characteristic. In this view, the cranial articular surface and the caudal articular processes facing ventrolaterally were noted. At the root of its transverse process was identified the small transverse foramen. In the rest of vertebrae, the dorsal and ventral tubercles of the transverse processes were identified and could be observed how the ventral tubercles were more prominent in the most caudal cervical vertebrae (Figure 1).

In relation to the dog head, the mass formation was evaluated by CT and it showed a characteristic rounded, well-defined lesion with non-homogeneous bone opacity. The 3D reconstruction allowed to analyse the extent of the bony lesions produced by this process. Images showed excellent anatomic details and the mass formation could be visualised. It was occupying the entire orbital region, extended from the

lateral part of the face, affecting the antero- inferior or maxillary border of the zygomatic bone ventrally, whereas more dorsally it was prolonged upward to the frontal bone (Figure 2).

The results obtained in this study confirm that three-dimensional CT reconstruction is an useful procedure to teach normal and clinical anatomy in the veterinary colleges. However, it is infrequently used in veterinary medicine, mainly due to the high cost and the lack of suitable design for large animals. The three-dimensional reconstruction compensates the difficulties in understanding the detailed anatomical CT cross-sections by which the examiner is confronted while studying the CT images [1]. 3D-reconstructions based on CT-datasets are excellently suited for generating spatial sense. Additionally, a single scan series can be applied for different anatomical problems. The resulting digital 3D-objects are readily available and can be employed for educational purposes for better comprehension of the difficult spatial relations of the different anatomical areas [10-11].

Today, the claims on the anatomical education in veterinary medicine have changed due to the considerable increase of modern medical imaging techniques. To analyze techniques such as computed tomography (CT) images, magnetic resonance (MR) images or ultrasound, the knowledge of cross sectional anatomy is an important prerequisite for proper interpretation. Admittedly, it is difficult for students and also for practitioners to imagine three-dimensional objects in space. The possibilities and convenience of 3D-reconstructions have already been demonstrated by generating virtual casts of normal and abnormal areas from different specimens [10-12]. The use of this imaging technology may facilitate teaching of anatomy to veterinary students by allowing the view of structures in a realistic, 3D manner and enables visualisation of bone, vascular network and selected soft tissue anatomy in a 3D image without superimposition of other structures, eliminating the difficulties of visualising the extension of processes and facilitates to see the invasive capacity of different types of neoplasias. In addition, this procedure eliminates the difficulties of visualising the different anatomic structures in pictures or line drawings used in most student anatomy texts.

IV. ACKNOWLEDGEMENTS

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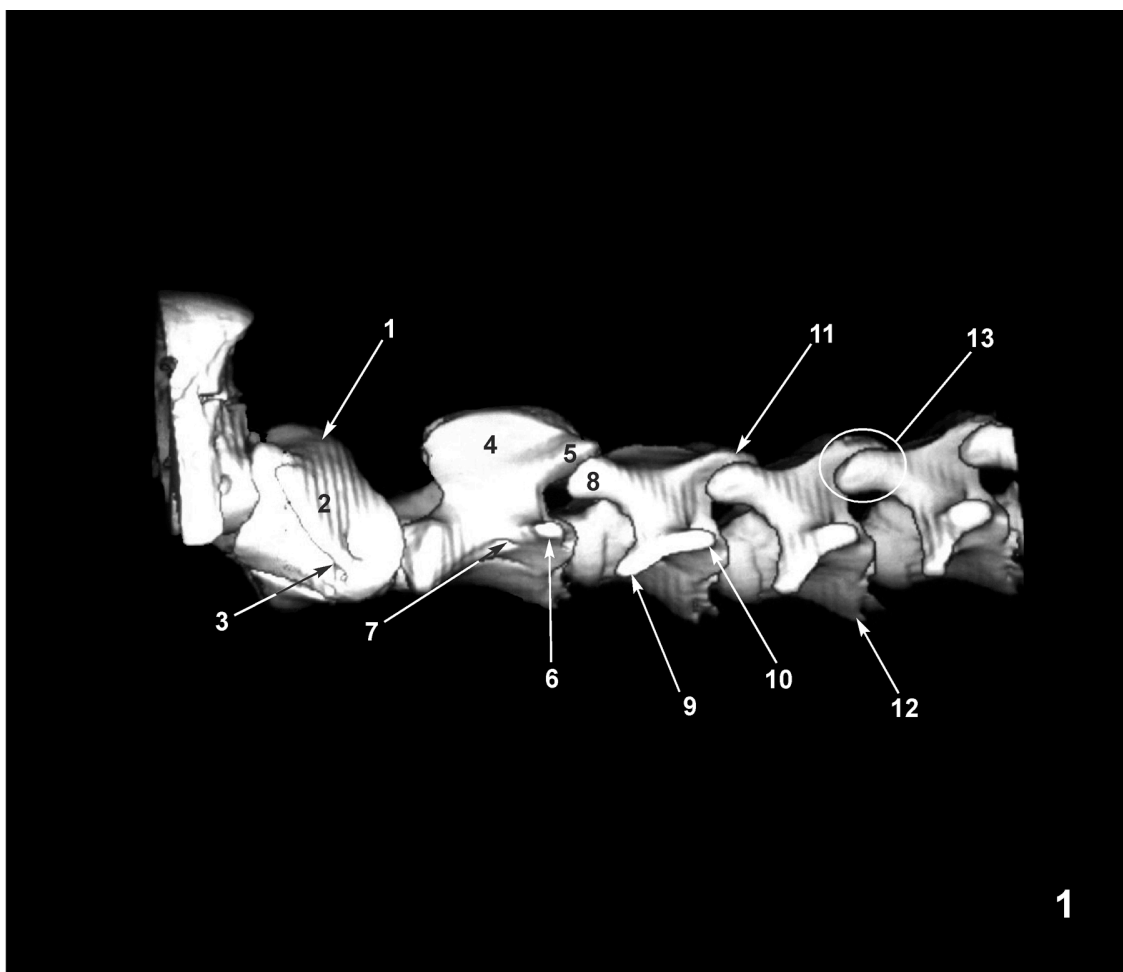


Figure 1. Three-dimensional reconstructed CT image of the cervical spine viewed from the lateral aspect. 1. Dorsal arch of atlas. 2. Transverse process (wing) of atlas. 3. Transversal foramen of atlas. 4. Spinous process of axis. 5. Caudal articular process of axis. 6. Transversal process of axis. 7. Transversal foramen of axis. 8. Cranial articular process of third vertebra. 9. Ventral tubercle of transverse process of third vertebra. 10. Dorsal tubercle of transverse process of third vertebra. 11. Caudal articular process of third vertebra. 12. Ventral crest on the body of cervical vertebrae. 13. Joint between articular processes.

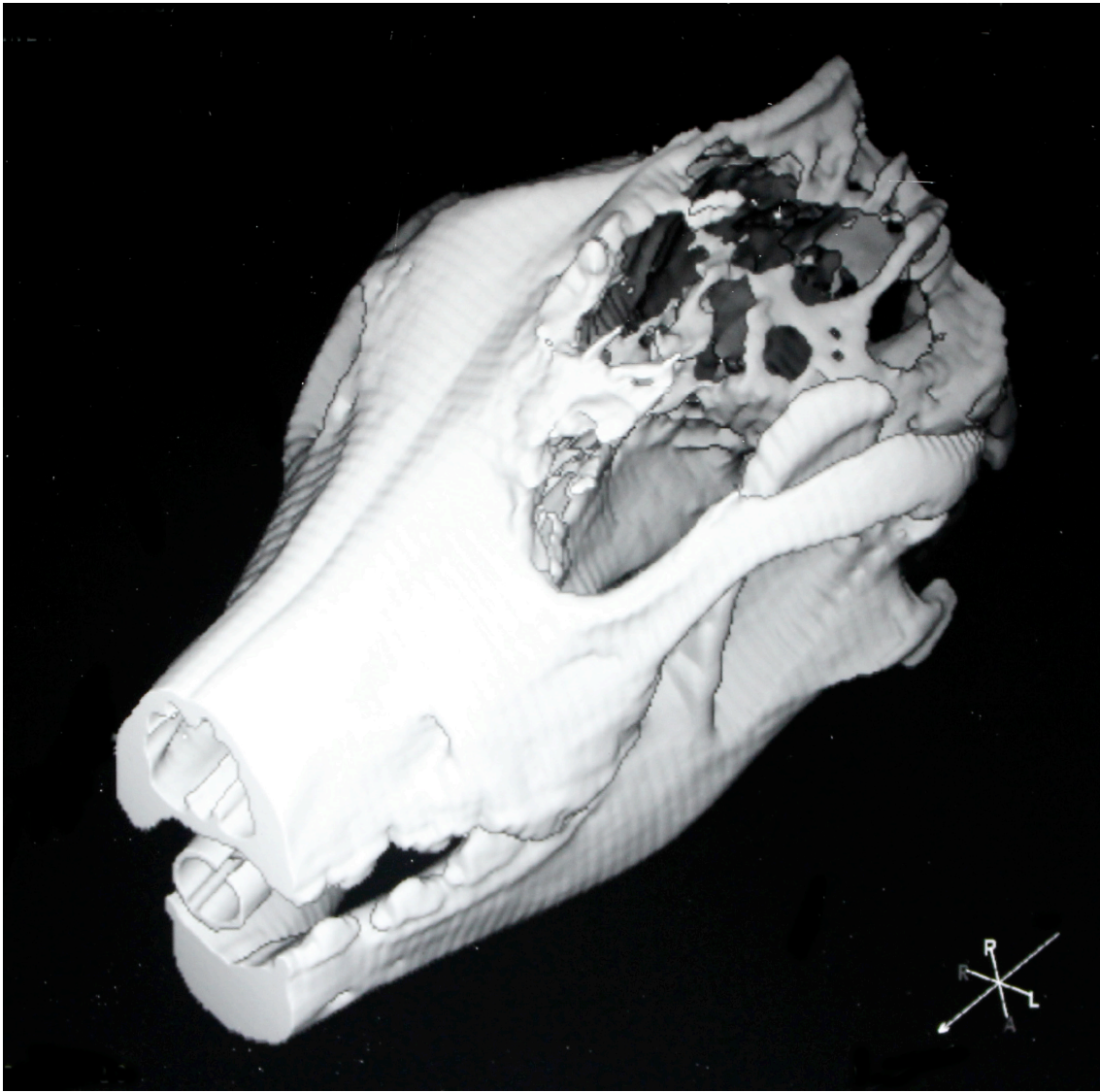


Figure 2. Three-dimensional reconstructed CT image of the skull. 3-D image with extraorbital involvement and focused on frontal and parietal areas, showing bone lysis and invasion into the cranial cavity.

Generating Multiple Random Exams Using Mathematica Package and L^AT_EX

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Abstract—In the framework of the European Higher Education Area, the assessment has been one of the most important aspects considered. In the Spanish Universities, one of the main differences with regard to the previous system is the incorporation of the continuous assessment to the evaluation process that is understood in several ways depending on the Universities, the courses and the lecturers. Focus on our context, a course of Mathematics of the first academic year in the Faculty of Business Administration at the University of Las Palmas de Gran Canaria (Spain), the continuous assessment has brought the preparation of a large amount of different tests to evaluate the students enrolled in it, therefore the incorporation of new tools and skills in order to make the teaching–learning process easier and more dynamic has become a need mainly in those degrees with a large number of students as the case we consider here. In this work we provide an efficient and effective way to elaborate random multiple-choice examination tests (although essay exams are also possible) by using *Mathematica* package and L^AT_EX in order to make easier to the lectures the preparation of a large number of mid-term tests for a large number of students.

Index Terms—Exam, L^AT_EX, Mathematica, Random, Test

I. INTRODUCTION

The teaching–learning process has become a dynamic process after the implementation of the European Higher Education Area that has brought the continuous assessment as an essential part of the evaluation process. Nevertheless, the way in which the continuous assessment is applied or understood depends on the subject, and in a way, on the lecturers. Some professors take into account the participation and the attendance as part of the assessment, whereas some others consider besides the final exam the delivery of some activities during the term. Likewise there are some Universities that have established regulations related to how the assessment should be integrated along the courses as the University of Barcelona did, [1]. In the framework of the Bologna process, for the case we analyze here, the main change in the assessment has consisted of introducing several mid-term tests in which some positive marks are accumulated, the purpose of these small exams in a course of Mathematics is to make easier to the students to pass the subject by taking exams of small group of contents, therefore the students have now more than one mark as part of the evaluation process. For the course considered here, Mathematics for Business, the continuous part of the evaluation represents a 40% of the final mark and consists in

two tests the students have to complete during the term. The students cannot retrieve or retake the tests to improve the mark obtained in the continuous assessment, consequently the score obtained in these two tests will be added to the score achieved in the final exam. A particular feature to be remarkable of the course we study here is that belongs to the first term of the first academic year in the Faculty of Economics, Business and Tourism, one of the most populated school at the University, it is precisely for that reason that there are many students in matriculated in the subject, eight groups of more than 80 students. In addition, according to the evaluation rules of the University, the final exam of a subject has to be the same for all the students, however due to constraints of time and space the mid-term exams have to be taken during the regular period of lessons hence a large quantity of different tests have to be prepared by the lecturers in order to prevent, on the one hand, cheating, and on the other hand the flow of information among the students because they carry out the examination in different hours along the same day. Moreover, to be fair and guarantee the students are evaluated under the same conditions the different test have to be prepared with the same level of difficulty, in short it is necessary a previous hard work consisting on preparing different exams corresponding to different versions and later on controlling the process of the exam.

In this work we provide an efficient and effective way to elaborate random multiple choice examination tests (papers are also possible) by using *Mathematica* (see [2]) and L^AT_EX. The reader interesting in this compiler are invited to read the work of [3]. Using these two tools we are able to generate in an easy way different PDF documents created by L^AT_EX. At the same time solutions are provided to easily correct the exams, these solutions are available not only for lecturers but also could be given to the students when the examination process has concluded, thus they could proceed to make a correction by themselves.

The work is structured as follows. The methodology and the results are given in Section II and Conclusions in Section III. An Appendix Section is provided at the end of the work to show the main documents needed to get the target and the *Mathematica* code.

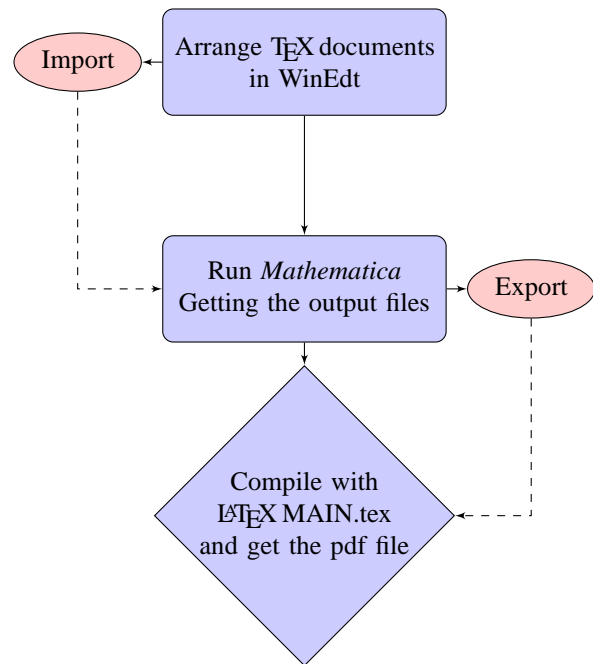
II. METHODOLOGY AND RESULTS

In order to get the target we need firstly to prepare in \TeX commands two kinds of files and a main file which will be running at the end to generate the exams. We recommend to use the WinEdt editor, which is a powerful and versatile all-purpose text editor for Windows with a strong predisposition towards the creation of \LaTeX documents. This editor is available (previous fee) in the web page <http://www.winedt.com/>. Any other text editor is possible to be used but the main advantage of WinEdt is that allow to dealing different lines as a unique line by using wrapping (see the manual of WinEdt available in the web). The first type of \TeX files includes the different questions which are going to be part of the exam. These files contain the banks of question to allow us to create a repository of test questions. In our example we have worked with five topics to be questioned to the students. They contain basic questions about Calculus and are (i) Domain of a function, (ii) Composition operator, (iii) Inverse of a function, (iv) Monotony of functions and (v) Integrals. The order of the questions in the exams are arranged in the order in which the material is explained in class, although the influence of the item sequence with the performance of the students on multiple choice exams does not significantly affect students exam scores as it has been analyzed by [4] among others and [5] even found that the order of questions has not statistically significant effect on exam scores, even after including variables that reflect differential student-specific human capital characteristics. We note that in this case we refer to functions of a real variable. Here, they are denoted as $t_1.tex$, $t_2.tex$, ..., $t_5.tex$, respectively. The other type of files are mentioned as $EXAMEN_1.tex$, $EXAMEN_2.tex$, ... The body of these types of files is the same but different for the case of we need to generate one exam, two different exams, etc. The main file to be compiled in \LaTeX includes only a preamble (as usual in all \LaTeX documents) and a main body with the usual entries and an input of the file between them containing the(s) exam(s) by using $\backslashinput\{exam\}$, where the exam.tex file was built automatically by *Mathematica*. An example of these types of files can be viewed in the Appendix Section of this work. The *Mathematica* code to get the different tex files is also given in the Appendix section.

All the *Mathematica* commands used are simple and standard and detailed information is provided after them into (**). As you can see Import is needed to get the appropriate files, Export to save the files generate by *Mathematica* and the main command to be used is Table together with Do, which uses the standard Wolfram Language iteration specification. Additionally to the files mentioned *Mathematica* generates the simple files date.tex, subject.tex, typeexam.tex, degree.tex and tableqa.tex in order to print into the file EXAMEN.tex the corresponding date of the exam, the subject, the type of the exam, the degree and the table of response where the students have to mark the response they consider that it is correct. *Mathematica* also provides the table of correct answers

(responses are labelled with the corresponding labels) which is saved in the file finaltable.tex. This final table including the right answers for all the generated models might be provided also to the students, needless to say that once the examination process has finished, so they might have an idea of the score of the exam in advance. An example with two types of exams with five questions is provided and the pdf file generated by \LaTeX is shown in the Appendix Section.

A simple organigram of the process is given below.



III. CONCLUSIONS

In this work we provide an efficient and effective way to elaborate random examination tests (papers are also possible) by using *Mathematica* package and \LaTeX . Using these two tools we are able to generate, in an easy way, different PDF documents created by \LaTeX . At the same time solutions are provided to easily correct them.

The questions on the generated exams include the topics in the same order they are presented in the contents of the course because in this way it has been decided at the moment of designing the output of the program but this order could be scrambled. Depending on the bank of questions for each topic the probability of repeating questions is lower. With regard to the answers, as the right questions are labeled the order in which they are shown could be scrambled with the automatic change in the complete solution table provided to the students in order they could have an idea of their marks.

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APPENDIX

Mathematica code

```

1 numberquestions = 5; (* write the number of questions *)
2 numex = 2; (* write the number of exams to generate *)
3 date = TextForm["January_15th_2015"];
4 (* write between commas the date of the exam *)
5 subject = TextForm["Maths"];
6 (* write between commas the subject *)
7 typeexam = TextForm["First_exercise"];
8 (* write between commas the type of exam *)
9 degree = TextForm["Degree_in_Business_Administration"];
10 (* write between commas the degree *)
11 tableqa = Grid[Table[{j, a, b, c}, {j, 1, numberquestions}],
12   Dividers -> All] // Text;
13 (* building the table of responses *)
14 Exam = Import["C:\\Users\\Desktop\\EXAMEN_" <> ToString[
15   numex] <> ".tex", "List"];
16 Export["C:\\Users\\Desktop\\date.tex", date, "Table"];
17 Export["C:\\Users\\Desktop\\EXAM.tex", Exam, "Table"];
18 Export["C:\\Users\\Desktop\\subject.tex", subject, "Table"];
19 Export["C:\\Users\\Desktop\\typeexam.tex", typeexam, "Table"];
20 Export["C:\\Users\\Desktop\\degree.tex", degree, "Table"];
21 Export["C:\\Users\\Desktop\\tableqa.tex", tableqa, "TeXFragment"];
22 allqr = Table[Import["C:\\Users\\Desktop\\t_" <> ToString[i] <>
23   ".tex",
24   "List"], {i, 1, numberquestions}];
25 (* importing files with all topics and questions and responses *)
26 m = Table[Length[allqr[[i]]], {i, 1, numberquestions}];
27 (* gives the length of topic i *)
28 allq = Table[allqr[[i]][[2* j - 1]], {i, 1, numberquestions}, {j, 1, m[[i]
29   ]/2}];
30 (* all questions of topic i *)
31 allr = Table[allqr[[i]][[2* j]], {i, 1, numberquestions}, {j, 1, m[[i]
32   ]/2}];
33 (* all responses of topic i *)
34 Do[
35   type = j; (* gives the version of the exam. Types 1,2,..., numex *)
36   ttj = Flatten[
37     Table[RandomChoice[allq[[i]], 1], {i, 1, numberquestions}]];
38   (* choose random question of topic i and convert to a table without
39     internal brackets *)
40   ptij = Flatten[Table[Position[allqr[[i]], ttj[[i]], {i, 1,
41     numberquestions}]];
42   (* position of the question chosen in the list t11all and convert to
43     a table without internal brackets *)
44   outexamen = TableForm[Table[ttj[[i]], {i, 1, numberquestions}]];
45   (* questions chosen *)
46   outanswers = TableForm[Table[allqr[[i]][[ ptij[[i]] + 1]], {i, 1,
47     numberquestions}]];
48   (* build the table of responses *)
49   Export["C:\\Users\\Desktop\\type_" <> ToString[j] <> ".tex",
50     type, "Table"];
51   Export["C:\\Users\\Desktop\\outexamen_" <> ToString[j] <> ".
52     tex", outexamen, "Table"];
53   Export["C:\\Users\\Desktop\\outanswer_" <> ToString[j] <> ".
54     tex", outanswers, "Table"];
55   {j, 1, numex}];
56 importresponses = Table[Import["C:\\Users\\Desktop\\outanswer_"
57   <> ToString[i] <> ".tex",

```

```

"List"], {i, 1, numex}];
finaltable = TableForm[Table[Insert[Insert[Insert[Insert[Riffle[
importresponses[[s]], "&"],
"\\\\", -1], "Type", 1], ":", 2], s, 2], {s, 1, numex}]];
Export["C:\\Users\\Desktop\\finaltable.tex", finaltable, "Table"];

```

Main document MAIN.tex (to be compiled)

```

\documentclass[10pt]{article}

\pagestyle{empty}
\def \R {{\rm I\kern -2.2pt R\hskip 1pt}}
\oddsidemargin=-0.25cm\evensidemargin=-0.25cm
\textwidth=180mm\textheight=270mm
\topmargin=-105pt\headheight=12truept
\headsep=25pt\footskip=17pt
\hoffset=1mm\voffset=4mm

```

```

\begin{document}
\input{exam}
\end{document}

```

Example of file EXAM_2.tex (arranged for two types of exams)

```

\newpage
\begin{titlepage} \noindent {\large \bf \input{subject}
\hfill {\input{date}}\ \input{typeexam}}\ \sc \input{title}
\hfill {Type \input{type_1}}\ \ \ \
{ \sc First name.....}
\hfill {\sc Surname.....}}\ \
\begin{enumerate} { \input{outexamen_1}} \end{enumerate}
\vspace{0.5cm}
\noindent {\sf Put in the following table a {\Large $\times$}
in the correct answer.}\ \ \
\Large \input{tableqa}
\end{titlepage}
\newpage
\begin{titlepage} \noindent {\large \bf \input{subject}
\hfill {\input{date}}\ \input{typeexam}}\ \sc \input{title}
\hfill {Type \input{type_2}}\ \ \ \
{ \sc First name.....}
\hfill {\sc Surname.....}}\ \
\begin{enumerate} { \input{outexamen_2}} \end{enumerate}
\vspace{0.5cm}
\noindent {\sf Put in the following table a {\Large $\times$}
in the correct answer.}\ \ \
\Large \input{tableqa}
\end{titlepage}
\begin{titlepage}
\vspace*{2cm}\noindent \Large
\input{degree} \Subject: \input{subject}\ \input{typeexam}
\input{date}
\vspace{1cm}
\begin{center}
{\sc Solutions}
\end{center}
\vspace{0.5cm}
\begin{table}[h]
\begin{center}
\begin{tabular}{cccccc}
\input{finaltable}\ \
\end{tabular}
\end{center}
\end{table}
\end{titlepage}

```

Example of file t_5.tex (a bank of questions)

In Figure 1 we show the code for the file t5.tex, a bank of questions corresponding to the topic Integration.

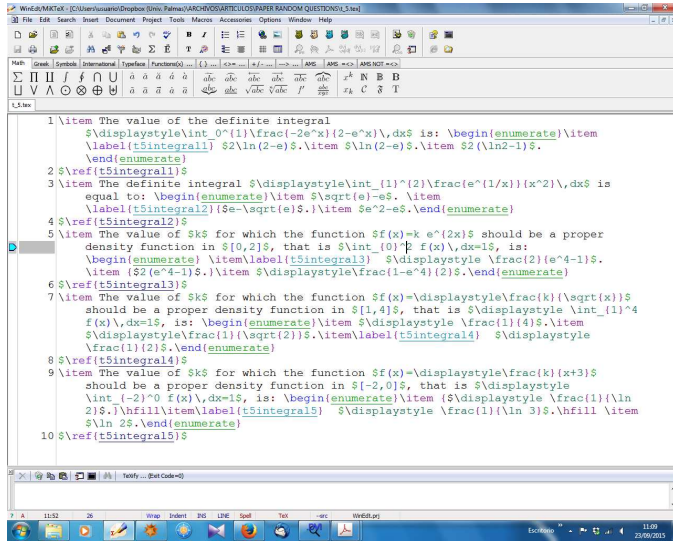


Fig. 1. File t_5.tex

Final exam

Figure 2 shows the final exam obtained after compiling the main document in L^AT_EX and get the pdf file.

- The domain of the function $f(x) = \frac{e^{2x-1}}{\sqrt{x}}$ is:
 - Dom(f) = (0, 1].
 - Dom(f) = (0, 1) ∪ (1, +∞).
 - Dom(f) = (0, +∞).
- Given the functions $f(x) = \sqrt{x-2}$, $g(x) = x^2 + 1$, then the domain of the function $(f \circ g)(x)$ is:
 - (-∞, -1] ∪ [1, +∞).
 - (-∞, -1) ∪ (1, +∞).
 - ∅.
- The inverse of the function $y = \frac{x+2}{x-2}$ is given by:
 - $x = \frac{2y+2}{1-y}$
 - $x = \frac{y-1}{2y+2}$
 - $x = \frac{2y+2}{y-1}$
- The function $f(x) = \frac{1+2x}{3x-1}$:
 - Is decreasing in its domain.
 - Has a local maximum in $x = 5$.
 - Is increasing in its domain.
- The value of the definite integral $\int_0^1 \frac{-2e^x}{2-e^x} dx$ is:
 - $2\ln(2-e)$.
 - $\ln(2-e)$.
 - $2\ln(2-1)$.

Put in the following table a × in the correct answer.

1	a	b	c
2	a	b	c
3	a	b	c
4	a	b	c
5	a	b	c

- The domain of the function $f(x) = \frac{\sqrt{x}}{x-1}$ is:
 - Dom(f) = [0, 1) ∪ (1, +∞).
 - Dom(f) = (0, 1) ∪ (1, +∞).
 - Dom(f) = (0, 1) ∪ [1, +∞).
- Given the functions $f(x) = 1 - x^2$ y $g(x) = x + 1$, then $(f \circ g)(x)$ is given by:
 - $x(x+2)$.
 - $2 - x^2$.
 - $-x(x+2)$.
- The inverse of the function $y = \frac{x+2}{x-2}$ is given by:
 - $x = \frac{2y+2}{1-y}$
 - $x = \frac{y-1}{2y+2}$
 - $x = \frac{2y+2}{y-1}$
- The function $f(x) = (x^2 - 3)e^x$ is:
 - Decreasing in \mathbb{R} (-3, 1).
 - Decreasing in $(-\infty, -3) \cup (1, +\infty)$.
 - Increasing in $(-3, +\infty)$.
- The value of k for which the function $f(x) = \frac{k}{\sqrt{x}}$ should be a proper density function in [1, 4], that is $\int_1^4 f(x) dx = 1$, is:
 - $\frac{1}{4}$.
 - $\frac{1}{\sqrt{2}}$.
 - $\frac{1}{2}$.

Put in the following table a × in the correct answer.

1	a	b	c
2	a	b	c
3	a	b	c
4	a	b	c
5	a	b	c

SOLUTIONS

Type 1 : 1c 2a 3c 4a 5a
Type 2 : 1a 2c 3c 4a 5c

Fig. 2. Final exam in pdf