IVET, an Interactive Veterinary Education Tool[1]

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ABSTRACT: The use of e-learning tools for medical teaching is a common practice, but similar tools do not exist for veterinary teaching. In this paper we present a fully web-based e-learning platform, denoted Interactive Veterinary Education Tool (**IVET**), which is designed to support teaching and learning in veterinary science. To make content creation easier, it provides theory, exercise, and image editors with functionalities to prepare exercises and theoretical content including two-dimensional (**2D**) images, three-dimensional (**3D**) models, and Digital Imaging and Communications in Medicine (**DICOM**) files, which can be manipulated by the users. It supports different types of exercises such as quizzes, 2D and 3D location exercises, and exercises based on multiplanar reconstructions from a set of animal scans (DICOM files). In addition, a correction strategy is defined for each type of exercise to automatically correct them and avoid the teacher to perform this process manually. All data is stored in a central repository, including the material prepared by the teacher and the solutions sent by the students, from which the system is able to compute some statistics, such as the evolution of the students and the final score of a course. By this way, teachers can use this information to carry out continuous assessment. All the resources such as 2D images, 3D models, and DICOM files are stored in the multimedia repository, included in the central one. To obtain real 3D models from animal scans, a manual segmentation process is also described. The platform has been reviewed by a group of teachers through an experimental test, and its functionalities have been compared to other veterinary e-learning tools from the literature.

Key words: anatomy, content creation, education, e-learning, veterinary, WebGL

INTRODUCTION

Current medical imaging devices, such as computed tomography (**CT**) and magnetic resonance imaging (**MRI**) scanners, are able to acquire precise information of body anatomy and function, and represent it as images. These images are a key element not only for diagnosis and treatment but also for teaching purposes, especially in degrees such as medicine and veterinary science. In the context of medicine, many computer-assisted learning packages with interactive three-dimensional (**3D**) anatomical models created from these images have been proposed (Mackenzie et al., 2003; Brenton et al., 2007; Dorosh et al., 2013; Smit et al., 2016). Moreover, the benefits of interactive animation and virtual models to train spatial thinking have been presented (Cohen and Hegarty, 2014), both in the medicine and the veterinary field (Lee et al., 2010; Peterson and Mlynarczyk, 2016). However, although the techniques used to create these packages and their corresponding models can also be applied in the context of veterinary science, the majority of tools have been proposed and are used only in the medical field.

Different studies confirmed the need for a modernization process in veterinary education (Short, 2002; Simões, 2010; Ozkadif and Eken, 2012; Valliyate et al., 2012), as well as the benefits of e-learning environments (Bing et al., 2011; Jan et al., 2012; Dorosh et al., 2013). Nonetheless, few environments have been proposed in this field, and most of them only deal with single parts of the animal body or with a particular species of animals (Tawfiek, 2011; El Sharaby et al., 2015; Raffan et al., 2017). To overcome this limitation, the Interactive Veterinary Education Tool (**IVET**) is proposed, a new educational platform specifically designed to support teaching and learning in veterinary science with no restrictions on animal species.

The IVET platform has been created taking into account subjects such as anatomy and morphology, where image-based information is essential. The aim of the platform is to provide functionalities to satisfy both teachers' and learners' needs. Focusing on teachers, IVET should make content creation and students' follow-up as easy as possible. Focusing on learners, the platform should be attractive enough to motivate students to work. Therefore, functionalities to interact with the material, to explore images and models, and to obtain immediate feedback, among others, are crucial. In this paper, the IVET platform will be described and compared with other state-of-the-art e-learning platforms for veterinary science.

MATERIALS AND METHODS

General architecture

The architecture of the proposed platform with its main modules and its functionalities is illustrated in Fig. 1 and described below.

Leaving the administrator aside, the platform supports two main user profiles: students and teachers. To log in to the platform, all the user profiles need a username and a password, and different interfaces are presented depending on each role. There is a central repository to store all the information such as the theoretical content, the exercises, and the solutions sent by the students, among others. Special attention is given to graphic information such as two-dimensional (**2D**) images, 3D models, and Digital Imaging and Communications in Medicine (**DICOM**) files, which are stored in the multimedia repository.

Multimedia repository

The multimedia repository stores all kind of graphic files from different species and different body parts, including 2D images, videos, 3D models, and DICOM files. As for the 2D images and the videos, they can usually be found in other resources, and it is not difficult to create new files. Regarding the 3D representations, including 3D models and multiplanar reconstructions (**MPR**), they present more difficulties. On the one hand, to obtain a DICOM file and represent it as a multiplanar reconstruction in the viewer, a proper medical device has to be used, such as a CT scanner. On the other hand, getting 3D surface models of a specific anatomical part can be more complicated. Most of the 3D models used in anatomy teaching are taken from general packages which are modeled following the information of the atlases, with no need for being fully realistic. However, if a 3D model is shown together with medical data, such as MRI and CT scans, as supported by the IVET platform, the 3D model has to match this data. To do so, the model has to be segmented using the scans as a reference.

The *model creation* module from Fig. 1 represents this preparation process. In the examples presented in this paper, the CMISS software (http://www.cmiss.org, last accessed September 18, 2018) was used to load the scans and perform the segmentation. Figure 2 shows the five steps required to segment a model: (a) get the medical data, which will be used as the guidelines for the segmentation, and in the example corresponds to a set of CT scans from a live pig with enough quality to avoid its pre-processing; (b) the model segmentation, using the CMISS software to add some nodes to the most representative scans to delimit the border of the model, and connecting them to create the exterior faces of a 3D surface model; (c) the conversion to a cubic model, transforming the current linear model (linear interpolation between nodes) to a cubic model (cubic Hermite interpolation, in this case), because the anatomy models needed are seldom linear, and their nodes are usually connected by curved lines to resemble real models; (d) the model post-processing, because although the linear to cubic conversion is properly handled by the CMISS software, sometimes the nodes have to be repositioned by loading the cubic model again and dynamically changing the position of the nodes (keeping the cubic interpolation), so that the edges of the faces can be fit to the scans; and (e) the conversion to the JavaScript Object Notation format (http://json.org, last accessed September 18, 2018), using the functionalities of the CMISS software, so that the WebGL environment is able to load the model.

Moreover, CMISS has the option to add fields to the nodes, so that additional information can be obtained, such as computing the volume of the model, the area of its surface, and other mathematical functions.

Implementation details

The proposed platform has been implemented using HTML5, JavaScript and CSS3 for the user interfaces, and PHP and MySQL for the communication with the server and the database. A JavaScript library has also been used to work with the WebGL functionalities, which allows the visualization of 3D representations. Hence, the platform has been designed to be used in any web browser without the need for installing any plug-in (Johnston et al., 2013).

Student functionalities

When students log in to the platform, they enter the *course viewer*, from which theory and exercises of the course can be accessed. If an exercise is accessed, a specific interface to send the solution is provided. Once a solution is sent, the correction process starts. The *correction* module obtains the correction strategy linked to the exercise, performs the correction, and returns feedback to the user. All the actions are stored in the system database, and used by the statistics module, which can build queries to get information about the students' progress, such as the number and type of errors for each exercise, and the time taken to complete them.

Teacher functionalities

When teachers log in to the platform, they can create a new course or edit an existing one using the *course editor*, assign it to a group of students using the *assignment editor*, and obtain some information about the students' performance using the *statistics* module, which can then be used to carry out continuous assessment of the course for each student. As for the first functionality, once a course is created, the *theory editor* and the *exercise editor* can be used to fill the course with content. Both editors are connected to the *image editor*, which is the responsible for dealing with images and the interaction with them. The editors allow the creation of new material, but also the option of loading an existing one from the system *database* and update it, so that they avoid the creation from scratch. All the created material is stored in the system database, which also registers information related to students, such as the exercises assigned to them and the solutions they send. All the graphical material is registered in the *multimedia repository*.

In addition, the exercises of the platform are also assigned a set of labels which identify the difficulty level, the application area, the user type to which they are addressed, and the creation date, among others.

As default, contents developed using the platform can only be accessed and edited by the teachers who created them, although the platform is prepared to give teachers the option to share them publicly.

Correction strategy

As represented in Fig. 1, the exercise editor allows the creation of different types of exercises, each one having a specific corrector with the corresponding correction strategy (*correction editor*).

Currently, the platform supports test exercises, which set out a multiple-choice question to the students; 2D location exercises, which ask them to mark a specific point over a 2D image; 3D location exercises, which ask them to select one or more 3D models from the ones displayed in the 3D viewer; and MPR exercises, which load the scans of an animal (DICOM files) and allow the students to move the basic anatomical planes (axial, sagittal and coronal) so that the intersection point of them is close to the point stated in the question.

Note that each type of exercise has a particular editor for the teacher to enter the correct solution, as the correction strategy is different. The platform has been implemented in a modular way, so that a new type of exercise can be added in the future without modifying the platform structure.

Comparison with other platforms

With the purpose of evaluating the usefulness of the IVET platform and its ability to overcome current limitations, it has been compared to other state-of-the-art e-learning platforms for veterinary science.

To identify these platforms, a search was performed considering ScienceDirect, PubMed, Scopus, and Google Scholar, and the following keywords: ‘veterinary’, ‘e-learning’, ‘distance’, ‘learning’, ‘web’, ‘anatomy’, ‘animal’, ‘education’, ‘teaching’, ‘virtual’, ‘computer’, ‘internet’, ‘interactive’, ‘3D’, ‘three-dimensional’. All the terms have been addressed in conjunction to increase the efficiency of possible outcomes. From this search, several results were obtained which were filtered considering only the ones related to anatomy teaching and veterinary education. The search results were reduced to the 46 most relevant publications. From these publications, a final selection of 11 was made (see Table 1 from Results and Discussion section), excluding the ones related to the human anatomy and the veterinary education overviews, and taking into account both the relationship with the veterinary field and the presentation of an e-learning tool.

Preliminary evaluation

A group of four different teachers recruited through personal contacts have performed a first evaluation of the platform. They are used to new technologies, and they use Microsoft PowerPoint to prepare the slides which support their lessons. The images they show in these slides are in common formats such as JPG/JPEG and PNG, including medical images; they seldom use DICOM files and medical imaging viewers to let the students practice. Some of them take advantage of 2D virtual atlases to complement their classes, but they almost never use 3D models or visualization techniques higher than 2D. Furthermore, their students cannot perform online exercises because they have not found a proper e-learning tool.

The platform has been introduced to them individually, while describing the different features and its functioning. After the first introduction, they have been able to test the platform as much as they needed, and then their opinion about it has been required by interviewing them. The main interest of this first evaluation is to know whether this platform can improve current teaching methodologies in the veterinary science, especially with the incorporation of interactive theory material and exercises which are based on 2D images, 3D models, and other medical imaging visualizations. In this sense, their opinion about the content creation process is also required. No questionnaire has been involved in this evaluation, but only the following open questions: (i) “Do you believe this platform could be useful for teaching?”, (ii) “Which functionalities would you highlight or eliminate?”, and (iii) “Would you use this platform as part of your teaching methodology?”.

RESULTS AND DISCUSSION

In this section, some of the main interfaces of IVET and the description of their main functionalities will be presented. Then, these functionalities will be discussed and compared to those from the selected e-learning platforms for veterinary science.

IVET interfaces and functionalities

The theory editor is illustrated in Fig. 3A, where the interface for a new content page is shown. A page can be considered similar to a single presentation slide. Under the main title of the interface, the path helps teachers know which topic or subtopic of the course they are editing. Teachers are able to select the language in which they want to write the content, which is divided in three main parts: the title, the subtitle, and the body of the page. The text of the content can be formatted by using features such as bold characters and subscripts. The image editor, which is also used in the exercise editor, is located on the left side of the theory editor. Different viewers can be alternated by using the corresponding tabs, which are placed above the viewer. These tabs, namely 2D, 3D, and MPR, vary depending on the exercise type because some of them do not allow all the viewers. In the case of the theory editor, all the viewers are allowed, so that all the tabs are visible. The interfaces for each tab will be described below, together with the exercise editor.

The theory viewer is illustrated in Fig. 3B, and it is what students see when accessing the theoretical content. Students can navigate and access through the content pages using the corresponding buttons. The main body of the interface is divided in two parts: the image viewer on the left hand, allowing the students to see the viewer in full screen mode, and to switch between the 2D, 3D, and MPR viewers, if they are visible; and the text viewer on the right hand.

The exercise editor presents different interfaces and functionalities depending on the exercise type. The editor for the test exercise is illustrated in Fig. 4A. Similar to the theory editor, and shared with the editors of the other exercise types, teachers can select the language, and enter the name and the description of the exercise, the question and its solution, and a tip to help students solve the exercise. Other common features are the option to assign a difficulty level to it, as well as some keywords and the user types to whom it is addressed, improving by this way the exercise filtering. Taking into account that an exercise can be reused, the last common feature allows to assign it to different topics. As for the specific features of the test exercise, the editor allows the teachers to add as many possible answers as they want. Each answer has its own feedback, so that teachers can customize the response to the students when they fail. Teachers can indicate the correct answers by checking the little box on the left of each answer. Regarding the image editor for the test exercise, it allows all kinds of graphic content. Figure 4A shows the interface for the 2D tab, which allows to upload new images, select them from the library, or delete them. The viewer also allows to pan and zoom the images, and their order can be changed using the arrows on the right.

The viewer for the test exercise is illustrated in Fig. 4B, and it also has some shared features with the other exercise viewers, such as the button to access the theory, the indices to navigate between the exercises, and the progress bar to show the percentage of completed exercises. At the bottom of the page, other common features are the tip button on the bottom-left corner, and the full screen button on the bottom-right one. Focusing on the specific features of the test exercise, the possible answers are embedded in the question box, and students can check as many of them as they want. They can also pan and zoom the image displayed in the viewer, and change it by using the bottom-right arrows, if there is more than one.

The editor for the 3D location exercise is illustrated in Fig. 5A, and only the image editor presents some differences with respect to the previous exercise. As it is a 3D location exercise, only the 3D tab is shown. Teachers can upload new 3D models or load them from the library, and they can pan, zoom, and rotate the 3D models in the viewer. They can also choose the solution models by selecting them from the list, or by selecting them directly in the 3D viewer.

The viewer for the 3D location exercise is illustrated in Fig. 5B, and students only have to select the models asked in the question and send their solution. The viewer also allows the students to pan, zoom, and rotate the 3D models to get better viewpoints.

Finally, the editor for the MPR exercise is illustrated in Fig. 6A. Similar to the 3D location exercise, only the MPR tab of the image editor is visible because only this kind of graphic representation is expected. Teachers can load DICOM files from the library, and they can pan, zoom, and rotate the MPR visualization, as well as move the anatomical planes by dragging them. The planes can also be moved using the corresponding boxes under the viewer (titled ‘axial’, ‘sagittal’, and ‘coronal’), and their intersection point is displayed in the box titled ‘centre’. As detecting the exact intersection point would be difficult for the students, teachers have the option to assign a 3D error radius represented in the viewer as a green sphere; if the students select an intersection point which lies inside the sphere, the solution will be considered to be correct.

The viewer for the MPR exercise is illustrated in Fig. 6B, where the students have to move the anatomical planes by dragging them directly in the viewer.

For more details about the interfaces and their functionalities, see the videos provided as supplemental material.

Comparison of IVET with the selected platforms

Before presenting a more thorough discussion, a brief description of the selected e-learning platforms for veterinary science is given.

Theodoropoulos et al. (1994) present a veterinary anatomy tutoring system covering gross anatomy, histology, and embryology, while Phillips et al. (2001) develop a technology-mediated alternative to print-based external study of a postgraduate unit in veterinary diagnostic imaging. Focusing on distance learning courses, Dale et al. (2005) explain their experience with a teaching and learning technology program (TLTP) project called CLIVE (Computer-aided Learning in Veterinary Education), and Ertmer and Nour (2007) describe a veterinary technology distance learning program based on instructional interactions in the context of two foundational physiology courses. Pop et al. (2013), on the other hand, present three e-learning platforms in veterinary undergraduate and post-graduate education and training. Other platforms are used as additional tools to enhance learning, especially in the context of canine anatomy, such as the ones described by Malinowski (2003), a multimedia project to assist veterinary technology students in learning canine skeletal anatomy in three dimensions; Linton et al. (2005), a computer-based anatomy program to help students study the dissection, osteology, and radiology of the canine head; and Raffan et al. (2017), a 3D interactive application about canine neuroanatomy for undergraduate veterinary education. However, other tools exist for the equine anatomy, such as the one developed by El Sharaby et al. (2015), which consists in a computer-facilitated learning program which comprises two modules about horse anatomy, and for the sheep anatomy, such as the one presented by Tawfiek (2011), a computer program about the virtual dissection of sheep including different parts of this animal's body. Finally, a more general tool for several farm animal species is described by Grizzle et al. (2008), defining a virtual teaching laboratory for Animal Sciences students taking a course in Reproductive Physiology and Lactation.

The platforms described above are a good complement to veterinary education. However, their provided functionalities are still far from the ones provided by e-learning platforms used in other fields such as the medical one (Brenton et al., 2007; Colucci et al., 2015; Smit et al., 2016; Xiberta and Boada, 2016; http://zygotebody.com, last accessed September 18, 2018). Generally, these include the possibility to control students' progress, and more advanced visualization functionalities, inspired by radiological viewers, which allow users to prepare educational content, such as case-based studies, where images play a main role. Moreover, little attention is given to content creation functionalities, being the preparation of material a very time demanding task. IVET aims to be a new educational platform for veterinary science with more advanced functionalities that approach those available in the medical field.

The selected platforms, including IVET, the proposed one, have been analyzed and compared considering a set of parameters grouped in four major areas (see Table 1). These parameters are represented as P_n and, in the analysis of a parameter over a platform, only ‘yes’ (+) or ‘no’ (-) are assigned as possible categories for the answer, so that it is easier to evaluate them. As a side note, the project presented by Dale et al. (2005) includes several modules under the same consortium, so that the evaluated parameters may not apply to all of them.

Note that most of the platforms are non-web-based (some of them are delivered in CD-ROM format), or they require the users to install one or more plug-ins to run the application in a web browser, such as the ones presented by Dale et al. (2005), Ertmer and Nour (2007), and Pop et al. (2013). Only two of them (Grizzle et al., 2008; El Sharaby et al., 2015) seem to work in a web browser without the need for any plug-ins, although this is not specified in the corresponding publications. Besides, none of them describes the possibility to run the application using a mobile device, such as a smartphone or a tablet. The IVET platform can run in any web browser without the need to install any plug-in, and it can also run in smartphones and tablets.

Regarding the content creation parameters, almost all the platforms offer theoretical content, and they usually have this content structured in topics, with the exception of the platforms presented by Phillips et al. (2001), which is case-structured; Tawfiek (2011), which is structured following some anatomical parts; and Raffan et al. (2017), which uses the features of the platform to build customized tutorials, making them more interactive, but complicating the content creation. The proposed platform provides theoretical content structured in topics, with the option for each topic to have as many subtopics as needed, and so on. Moreover, each topic and subtopic is divided in content pages, so that teachers can separate the content for each unit. Some of the platforms also integrate self-evaluation exercises to help students test their knowledge, but almost all of the exercises are quizzes, i.e. multiple-choice questions. Only Ertmer and Nour (2007) offer exercises which require the user to interact with images, as well as quizzes. The IVET platform provides different types of exercises, including quizzes, location problems, and other image-based exercises which require user interaction, such as the MPR exercises.

Focusing on the image-based content, all the platforms make use of 2D images to illustrate theory concepts or as a part of some exercises, and some of them try to build 3D representations to improve the students' spatial ability. However, almost all of the platforms which try to build such 3D representations make use of QuickTime Virtual Reality or similar techniques, which gather together a set of photographs of a model from different angles so that the user can rotate it as if it was a 3D model. Only Raffan et al. (2017) offer a 3D model reconstructed after segmenting a set of scans and manually smoothing the results. Besides, none of the platforms offer the possibility of reading DICOM files or interacting with an MPR visualization. The proposed platform is able to visualize 2D images, giving the option to pan and zoom them, and also 3D surface models and multiplanar reconstructions using a WebGL environment, that is, without the need for any plug-in. The scans for the MPR visualization are extracted from DICOM files, and the 3D surface models are manually segmented to obtain accurate results.

As for access to statistics, few platforms have the option for the teachers to track the students' work. Ertmer and Nour (2007) provide a full tracking of the students' actions, while Pop et al. (2013) allow to access the students' results and Grizzle et al. (2008)

only offer the option to know the number of quizzes attempted by the students. The proposed platform allows to track the solutions sent by the students, the number of attempts and the errors, and the date and time they submitted the answers. The platform is able to automatically correct all the exercises, and it also computes different final scores based on the completed exercises, the correct ones, and the number of attempts.

Finally, the support that each platform offers with respect to the communication between the student and the teacher is evaluated, and also how the platforms collect the users' impressions to perform improvements. Only Ertmer and Nour (2007) and Phillips et al. (2001) provide a communication channel, the former using a bulletin board where users can post messages and earn points if the participation is relevant, and the latter offering it as a chat. As for the testing, seven platforms have been evaluated by users, from which four have provided a survey to the students to analyze their strengths and weaknesses and to carry out improvements. In this case, the IVET platform does not provide a direct communication channel between students and teachers, and it does not offer the option for the users to send suggestions. Both functionalities are planned to be included in the future, as well as the preview of the theoretical content and the exercises when teachers create them, so that they can check what the students will see; the integration of a helping system to guide the students through the solving process; and a tutoring system based on the students' results, suggesting exercises of different difficulty levels depending on their progress. Extending the functionalities based on image interaction, such as adding annotations over the images and models, is also considered.

Teachers' impressions

Although the previous comparison indicates that the proposed platform has some advantages with respect to the other ones, a group of teachers have been interviewed as a preliminary evaluation to reinforce these results. Given that there is almost no platform which offers interactive theory and exercises in veterinary science, their opinion has been highly favorable, and no important suggestions have been made to improve it. They have valued the option to easily enter their teaching material to the platform, as the structure of the IVET's theory viewer is slide-based, as well as the intuitive and fast content creation process, which enables them not to start from scratch. They have also appreciated the option to assign interactive exercises to their students, as well as the automatic correction and scoring, as they were not aware of any such platform which allows so. Thus, the overall impression is that IVET is a novel and useful tool which allows a high degree of interactivity between the students and the teaching material. They believe this platform could be useful for teaching, and they would use it as part of their teaching methodology.

This first evaluation, with a very small sample, has been performed only to find out whether the development of this platform makes sense. The obtained results have encouraged the preparation of a complete course to carry out a new experiment with students which will lead to a deeper evaluation of the platform using a specific questionnaire to assess its usability, content, and other related parameters.

CONCLUSION

An e-learning web-based platform (IVET) has been designed to support teaching and learning in veterinary science. It supports 2D images, 3D models, and MPR visualizations, and the modular design of the platform allows the creation of several exercises to interact with these graphical resources, thus increasing learners' motivation. The IVET platform also includes some editors to facilitate the content creation process and ensure that teachers can create a new course in a fast and efficient way, including specific strategies to automatically correct the exercises. We think that the IVET platform is a highly useful tool for veterinary science teachers and learners as we have not found any other platform in the literature which offers its level of interactivity.

LITERATURE CITED

Bing, J., S. Pratt-Phillips, L. A. Gillen, and C. E. Farin. 2011. Undergraduate performance in a domestic animal laboratory taught via distance education. Journal of Animal Science 89:297-301. doi:10.2527/jas.2010-3114.

Brenton, H., J. Hernandez, F. Bello, P. Strutton, S. Purkayastha, T. Firth, and A. Darzi. 2007. Using multimedia and Web3D to enhance anatomy teaching. Computers & Education 49:32-53. doi:10.1016/j.compedu.2005.06.005.

Cohen, C. A., and M. Hegarty. 2014. Visualizing cross sections: training spatial thinking using interactive animations and virtual objects. Learning and Individual Differences 33:63-71. doi:10.1016/j.lindif.2014.04.002.

Colucci, P. G., P. Kostandy, W. R. Shrauner, E. Arleo, M. Fuortes, A. S. Griffin, Y. H. Huang, K. Juluru, and A. J. Tsiouris. 2015. Development and utilization of a web-based application as a robust radiology teaching tool (RadStax) for medical student anatomy teaching. Academic Radiology 22:247-255. doi:10.1016/j.acra.2014.09.014.

Dale, V. H. M., G. McConnell, A. Short, and M. Sullivan. 2005. Ten years of CLIVE (Computer-aided Learning in Veterinary Education) in the United Kingdom. Journal of Veterinary Medical Education 32:47-50. doi:10.3138/jvme.32.1.47.

Dorosh, K., S. Bhattacharyya, P. Haase, and M. Johnson. 2013. Effectiveness of a dynamic cross-sectional anatomy learning tool (3D-X) at improving students' ability to interpret CT images. Medical Science Educator 23:364-376. doi:10.1007/BF03341648.

El Sharaby, A. A., M. A. M. Alsafy, and S. A. A. El-Gendy. 2015. Equine Anatomedia: development, integration and evaluation of an e-learning resource in applied veterinary anatomy. International Journal of Morphology 33:1577-1584. doi:10.4067/S0717-95022015000400063.

Ertmer, P. A., and A. Y. M. Nour. 2007. Teaching basic medical sciences at a distance: strategies for effective teaching and learning in internet-based courses. Journal of Veterinary Medical Education 34:316-324. doi:10.3138/jvme.34.3.316.

Grizzle, J. M., A. M. Saxton, P. Snow, and C. Edmonds. 2008. A virtual laboratory for undergraduate instruction in domestic animal reproductive physiology: help or hindrance? NACTA Journal 52:49-54.

Jan, L. J. G., A. de Kruif, and M. Valcke. 2012. Differential impact of unguided versus guided use of a multimedia introduction to equine obstetrics in veterinary education. Computers & Education 58:1076-1084. doi:10.1016/j.compedu.2011.11.006.

Johnston, S., L. Renambot, and D. Sauter. 2013. Employing WebGL to develop interactive stereoscopic 3D content for use in biomedical visualization. Proc. SPIE 8649:864905. doi:10.1117/12.2007594.

Lee, H., J. Kim, Y. Cho, M. Kim, N. Kim, and K. Lee. 2010. Three-dimensional computed tomographic volume rendering imaging as a teaching tool in veterinary radiology instruction. Veterinarni Medicina 55:603-609.

Linton, A., R. Schoenfeld-Tacher, and L. R. Whalen. 2005. Developing and implementing an assessment method to evaluate a virtual canine anatomy program. Journal of Veterinary Medical Education 32:249-254. doi:10.3138/jvme.32.2.249.

Mackenzie, J., G. Baily, M. Nitsche, and J. Rashbass. 2003. Gaming technologies for anatomy education. http://homes.lmc.gatech.edu/~nitsche/download/MackenzieBaileyNitscheRashbass_IV03.pdf (Accessed 18 September 2018).

Malinowski, R. 2003. 3D K9: Using Quicktime VR to teach veterinary anatomy. Master's thesis. Michigan State University, East Lansing, USA.

Ozkadif, S., and E. Eken. 2012. Modernization process in veterinary anatomy education. Energy Education Science and Technology Part B: Social and Educational Studies 4:957-962. doi:10.1109/34.485529.

Peterson, D. C., and G. S. A. Mlynarczyk. 2016. Analysis of traditional versus three-dimensional augmented curriculum on anatomical learning outcome measures. Anatomical Sciences Education 9:529-536. doi:10.1002/ase.1612.

Phillips, R., R. Pospisil, and J. L. Richardson. 2001. The use of a QTVR image database for teaching veterinary radiology and diagnostic ultrasound to distance education students. Australasian Journal of Educational Technology 17:96-114. doi:10.14742/ajet.1775.

Pop, A., G. Predoi, and V. Andronie. 2013. Interactive e-learning for veterinary medicine students and practitioners. Scientific Works. Series C. Veterinary Medicine 59:131-134.

Raffan, H., J. Guevar, M. Poyade, and P. M. Rea. 2017. Canine neuroanatomy: development of a 3D reconstruction and interactive application for undergraduate veterinary education. PLoS One 12(2):e0168911. doi:10.1371/journal.pone.0168911.

Short, N. 2002. The use of information and communication technology in veterinary education. Research in Veterinary Science 72:1-6. doi:10.1053/rvsc.2001.0531.

Simões, J. C. C. 2010. Information communication technology applied to veterinary education in early XXI century. Veterinaria.com.pt 3:e1.

Smit, N., C. W. Hofstede, A. Kraima, D. Jansma, M. deRuiter, E. Eisemann, and A. Vilanova. 2016. The Online Anatomical Human: web-based anatomy education. Proc. Eurographics - Education Papers 2016:37-40. doi:10.2312/eged.20161025.

Tawfiek, M. G. 2011. Preparation of audiovisual aids for use in teaching veterinary anatomy. PhD Diss. Beni-Suef University, Beni Suef, Egypt.

Theodoropoulos, G., V. Loumos, and J. Antonopoulos. 1994. A veterinary anatomy tutoring system. Computer Methods and Programs in Biomedicine 42:93-98. doi:10.1016/0169-2607(94)90045-0.

Valliyate, M., N. G. Robinson, and J. R. Goodman. 2012. Current concepts in simulation and other alternatives for veterinary education: a review. Veterinarni Medicina 57:325-337.

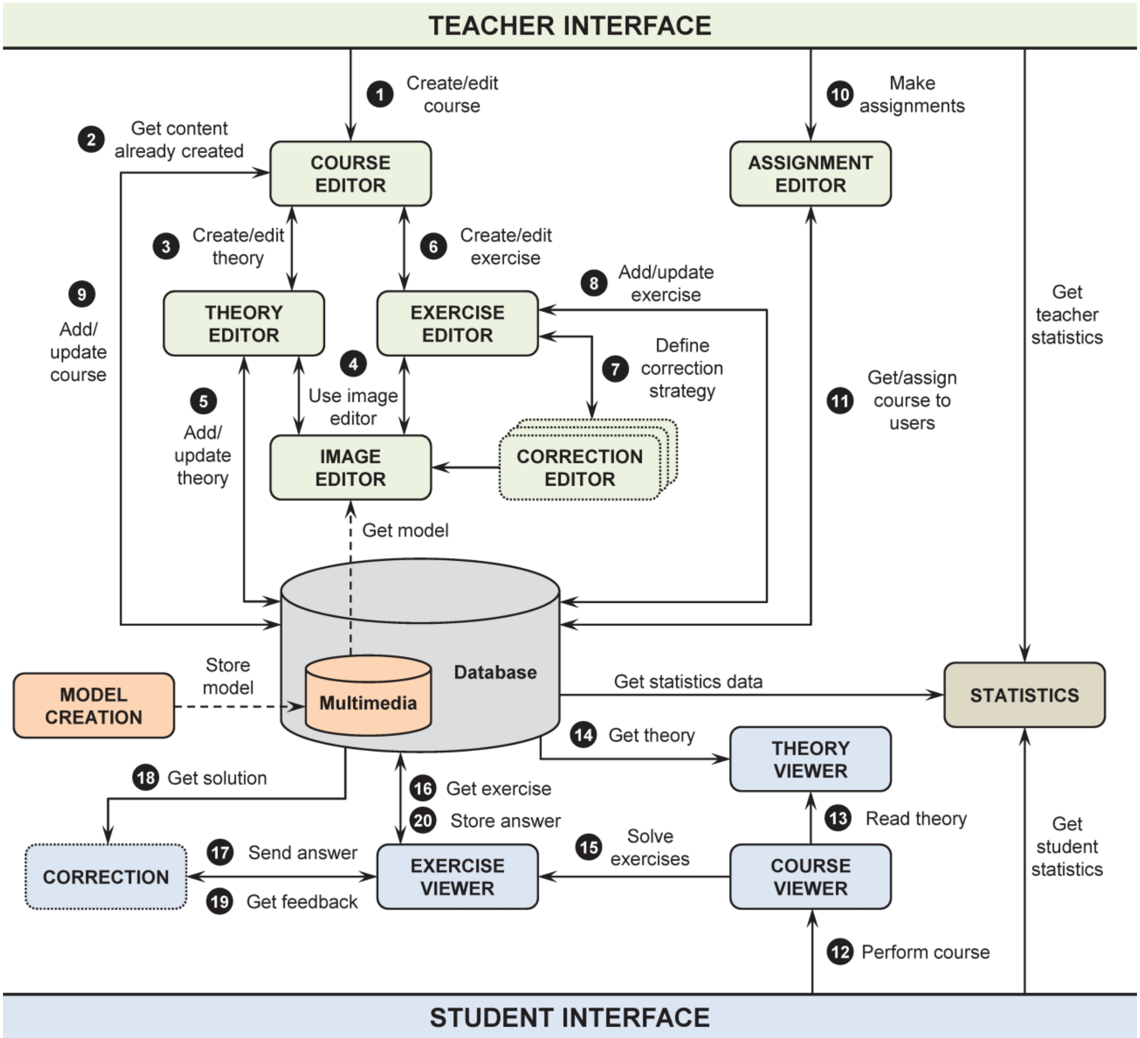
Xiberta, P., and I. Boada. 2016. A new e-learning platform for radiology education (RadEd). Computer Methods and Programs in Biomedicine 126:63-75. doi:10.1016/j.cmpb.2015.12.022.

Table 1. Comparison of state-of-the-art e-learning platforms for veterinary science

	Accessibility	**Content creation**					**Statistics**	**Others**	
	Fully web-based	Theory	Exercises	Image			Statistics	Community	Suggestions
				2D	3D	MPR			
	P_1	P_2	P_3	$P_{4.1}$	$P_{4.2}$	$P_{4.3}$	P_5	P_6	P_7
Theodoropoulos et al. (1994)	-	+	+	+	-	-	-	-	-
Phillips et al. (2001)	-	+	-	+	+	-	-	+	-
Malinowski (2003)	-	-	-	+	+	-	-	-	+
Dale et al. (2005)	-	+	-	+	+	-	-	-	-
Linton et al. (2005)	-	+	-	+	+	-	-	-	+
Ertmer and Nour (2007)	-	+	+	+	-	-	+	+	+
Grizzle et al. (2008)	+	-	+	+	-	-	+	-	-
Tawfiek (2011)	-	+	+	+	+	-	-	-	-
Pop et al. (2013)	-	+	+	+	-	-	+	-	-
El Sharaby (2015)	+	+	-	+	-	-	-	-	+
Raffan et al. (2017)	-	+	+	+	+	-	-	-	-
IVET	+	+	+	+	+	+	+	-	-

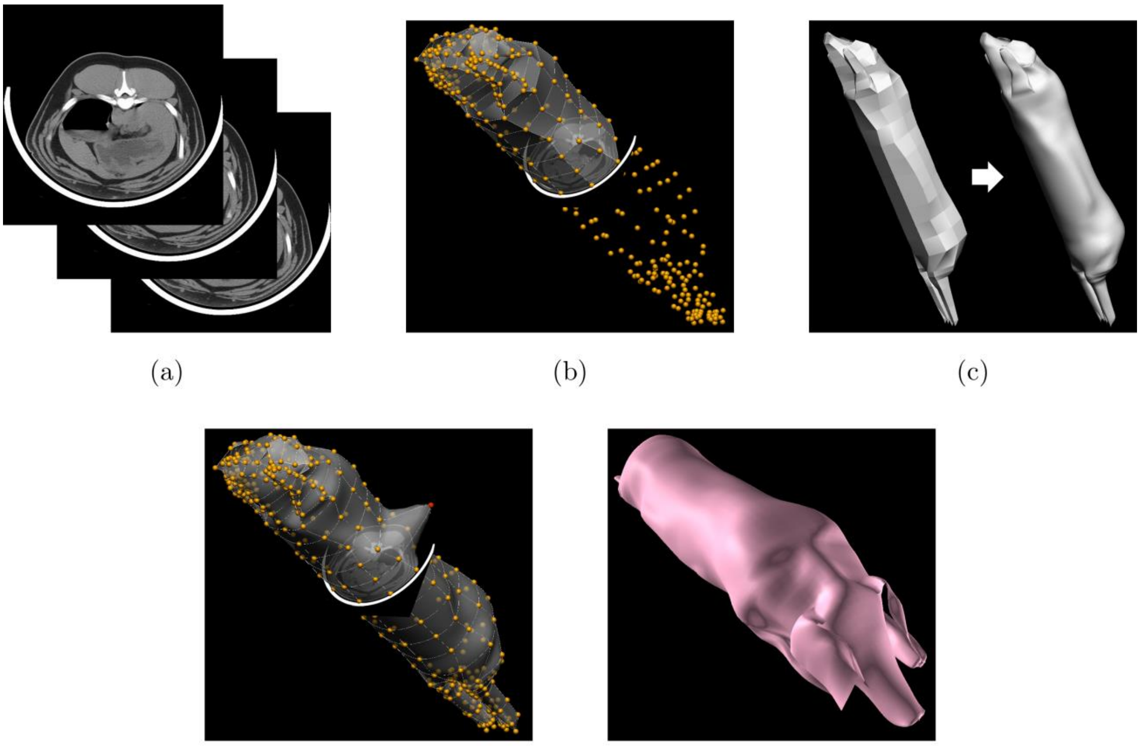
P_1: fully web-based platforms (no plug-ins), P_2: platforms which support theory, P_3: platforms which support self-evaluation exercises, P_4: platforms which support images, distinguishing between ($P_{4.1}$) the use of two-dimensional (**2D**) images, ($P_{4.2}$) the use of three-dimensional (**3D**) representations, and ($P_{4.3}$) the use of multiplanar reconstructions (**MPR**), P_5: platforms which support statistics, P_6: platforms with community support, P_7: platforms with a suggestions area.

Figure 1.



TEACHER INTERFACE
1 Create/edit course
2 Get content already created
COURSE EDITOR
10 Make assignments
ASSIGNMENT EDITOR
3 Create/edit theory
6 Create/edit exercise
8 Add/update exercise
9 Add/ update course
THEORY EDITOR
EXERCISE EDITOR
Get teacher statistics
4 Use image editor
7 Define correction strategy
11 Get/assign course to users
5 Add/ update theory
IMAGE EDITOR
CORRECTION EDITOR
Get model
Store model
MODEL CREATION
Multimedia
Database
Get statistics data
STATISTICS
14 Get theory
THEORY VIEWER
18 Get solution
16 Get exercise
20 Store answer
13 Read theory
Get student statistics
17 Send answer
CORRECTION
EXERCISE VIEWER
15 Solve exercises
COURSE VIEWER
19 Get feedback
12 Perform course
STUDENT INTERFACE

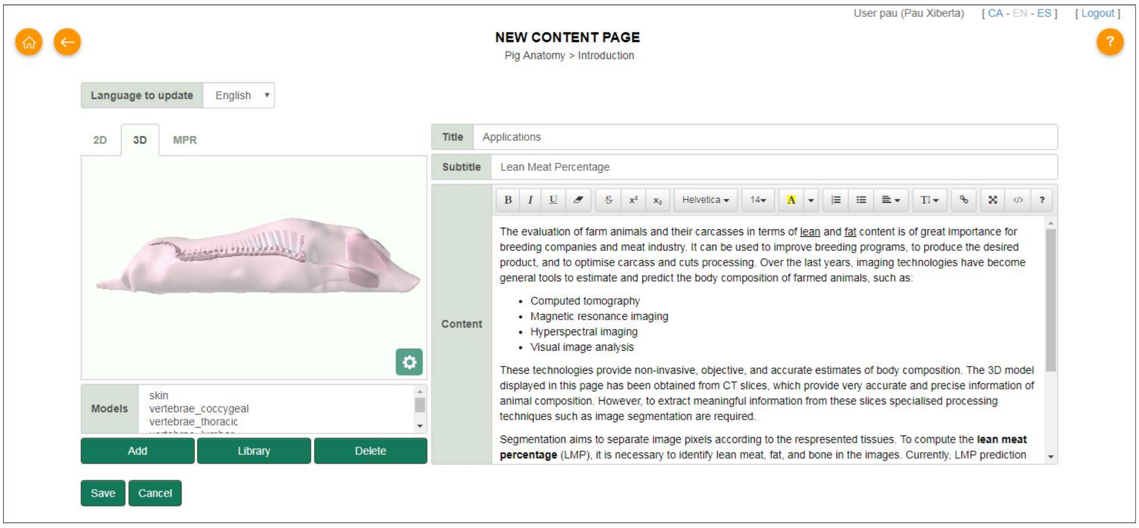
Figure 2.



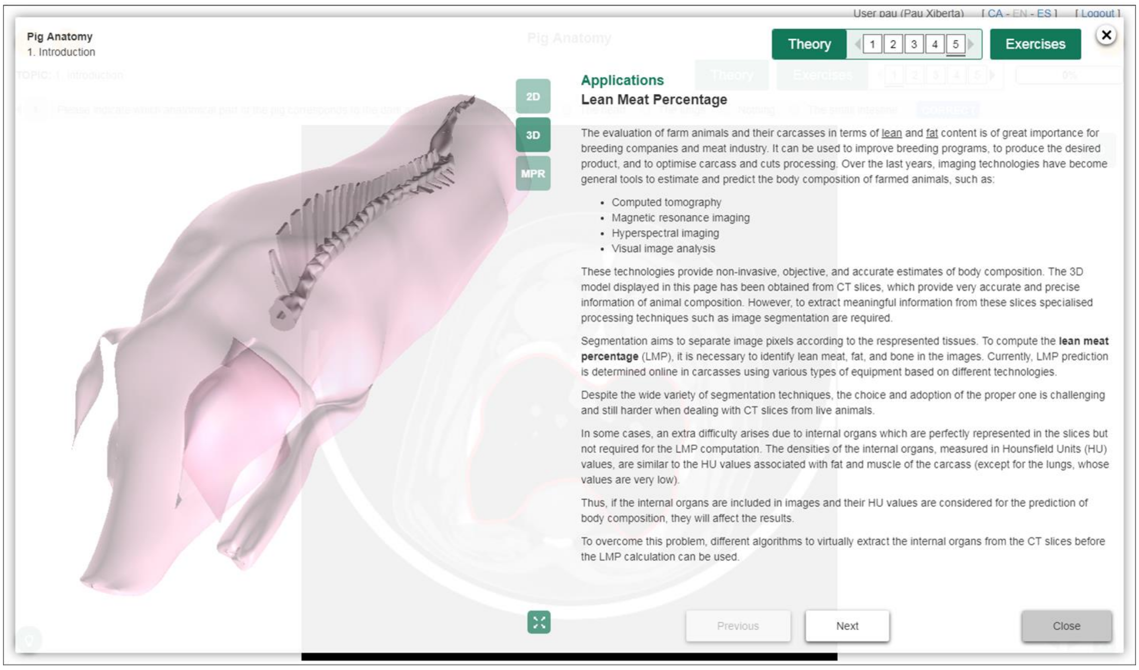
(a) (b) (c)

(d) (e)

Figure 3.

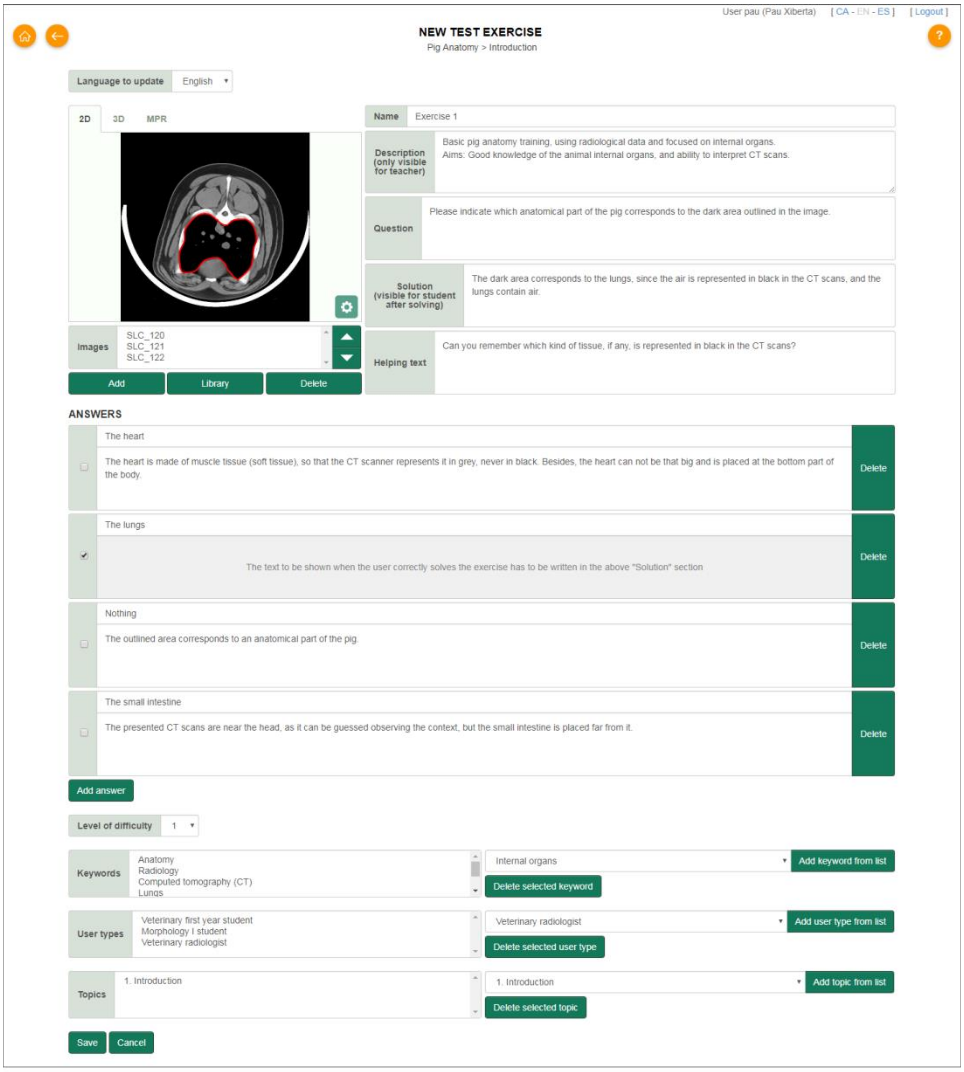

User pau (Pau Xiberta) [CA - EN - ES] [Logout]
NEW CONTENT PAGE
Pig Anatomy > Introduction
Language to update English
2D 3D MPR
Title Applications
Subtitle Lean Meat Percentage
Content
The evaluation of farm animals and their carcasses in terms of lean and fat content is of great importance for breeding companies and meat industry. It can be used to improve breeding programs, to produce the desired product, and to optimise carcass and cuts processing. Over the last years, imaging technologies have become general tools to estimate and predict the body composition of farmed animals, such as:
Computed tomography
Magnetic resonance imaging
Hyperspectral imaging
Visual image analysis
These technologies provide non-invasive, objective, and accurate estimates of body composition. The 3D model displayed in this page has been obtained from CT slices, which provide very accurate and precise information of animal composition. However, to extract meaningful information from these slices specialised processing techniques such as image segmentation are required.
Segmentation aims to separate image pixels according to the respresented tissues. To compute the lean meat percentage (LMP), it is necessary to identify lean meat, fat, and bone in the images. Currently, LMP prediction
Models skin vertebrae_coccygeal vertebrae_thoracic
Add Library Delete
Save Cancel

(a)

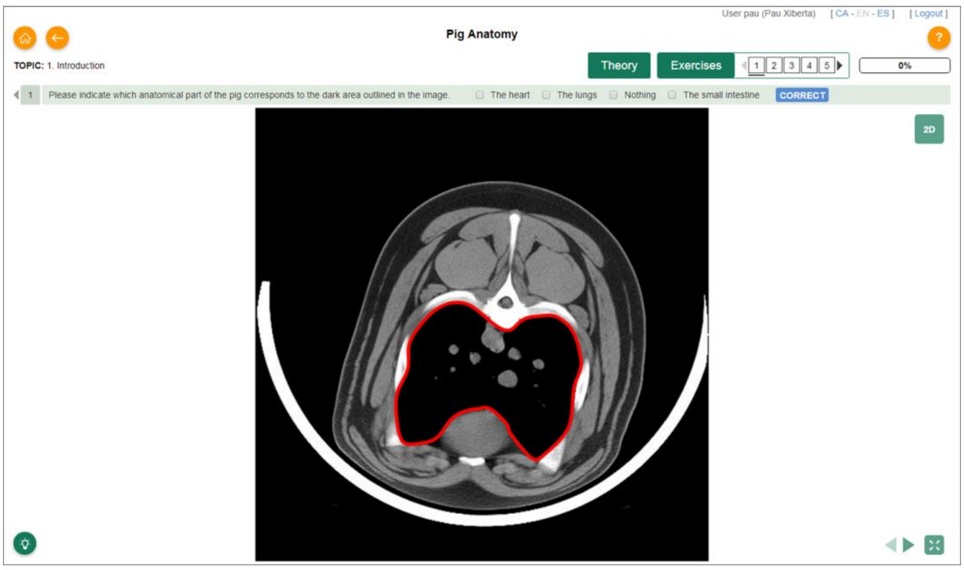

User pau (Pau Xiberta) [CA - EN - ES] [Logout]
Pig Anatomy
1. Introduction
Theory 1 2 3 4 5 Exercises
2D
3D
MPR
Applications
Lean Meat Percentage
The evaluation of farm animals and their carcasses in terms of lean and fat content is of great importance for breeding companies and meat industry. It can be used to improve breeding programs, to produce the desired product, and to optimise carcass and cuts processing. Over the last years, imaging technologies have become general tools to estimate and predict the body composition of farmed animals, such as:
Computed tomography
Magnetic resonance imaging
Hyperspectral imaging
Visual image analysis
These technologies provide non-invasive, objective, and accurate estimates of body composition. The 3D model displayed in this page has been obtained from CT slices, which provide very accurate and precise information of animal composition. However, to extract meaningful information from these slices specialised processing techniques such as image segmentation are required.
Segmentation aims to separate image pixels according to the respresented tissues. To compute the lean meat percentage (LMP), it is necessary to identify lean meat, fat, and bone in the images. Currently, LMP prediction is determined online in carcasses using various types of equipment based on different technologies.
Despite the wide variety of segmentation techniques, the choice and adoption of the proper one is challenging and still harder when dealing with CT slices from live animals.
In some cases, an extra difficulty arises due to internal organs which are perfectly represented in the slices but not required for the LMP computation. The densities of the internal organs, measured in Hounsfield Units (HU) values, are similar to the HU values associated with fat and muscle of the carcass (except for the lungs, whose values are very low).
Thus, if the internal organs are included in images and their HU values are considered for the prediction of body composition, they will affect the results.
To overcome this problem, different algorithms to virtually extract the internal organs from the CT slices before the LMP calculation can be used.
Previous Next Close

(b)

Figure 4.

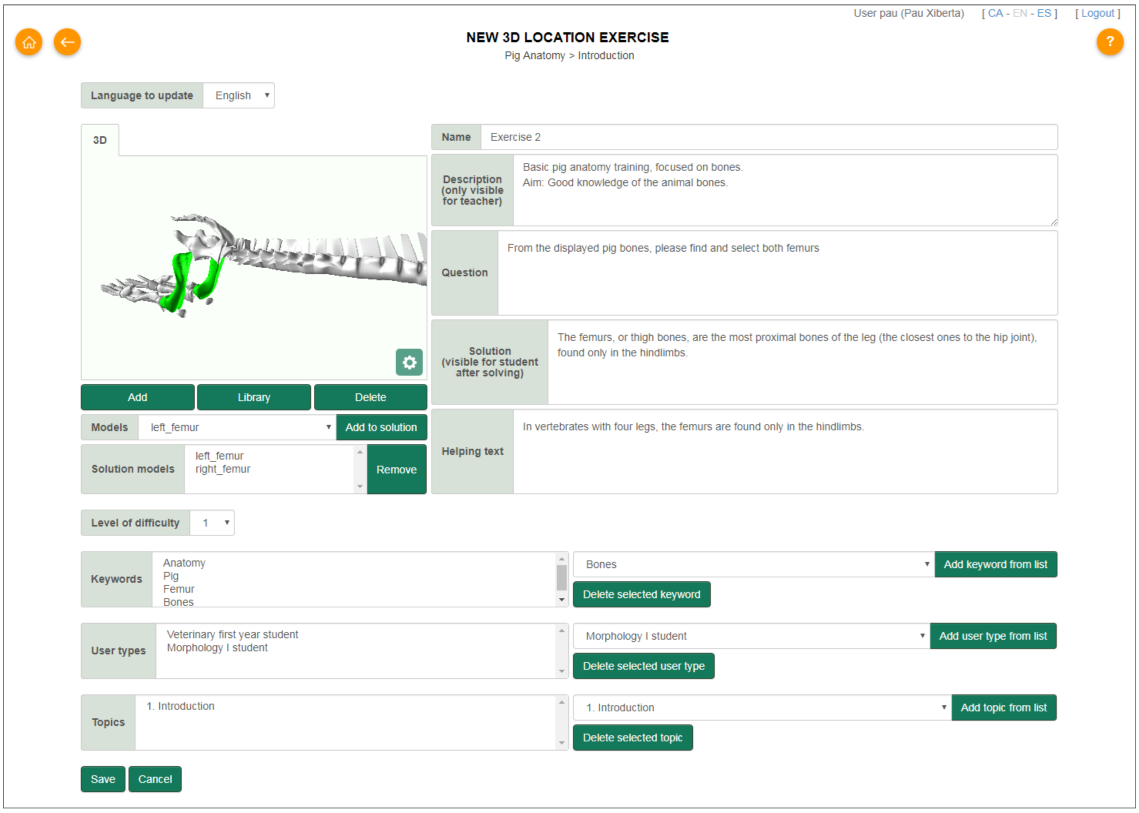

User pau (Pau Xiberta) [CA - EN - ES] [Logout]
NEW TEST EXERCISE
Pig Anatomy > Introduction
Language to update
English
2D
3D
MPR
Name
Exercise 1
Description (only visible for teacher)
Basic pig anatomy training, using radiological data and focused on internal organs.
Aims: Good knowledge of the animal internal organs, and ability to interpret CT scans.
Question
Please indicate which anatomical part of the pig corresponds to the dark area outlined in the image.
Solution (visible for student after solving)
The dark area corresponds to the lungs, since the air is represented in black in the CT scans, and the lungs contain air.
Images
SLC_120
SLC_121
SLC_122
Helping text
Can you remember which kind of tissue, if any, is represented in black in the CT scans?
Add
Library
Delete
ANSWERS
The heart
The heart is made of muscle tissue (soft tissue), so that the CT scanner represents it in grey, never in black. Besides, the heart can not be that big and is placed at the bottom part of the body.
Delete
The lungs
The text to be shown when the user correctly solves the exercise has to be written in the above "Solution" section
Delete
Nothing
The outlined area corresponds to an anatomical part of the pig.
Delete
The small intestine
The presented CT scans are near the head, as it can be guessed observing the context, but the small intestine is placed far from it.
Delete
Add answer
Level of difficulty
1
Keywords
Anatomy
Radiology
Computed tomography (CT)
Lungs
Internal organs
Add keyword from list
Delete selected keyword
User types
Veterinary first year student
Morphology I student
Veterinary radiologist
Veterinary radiologist
Add user type from list
Delete selected user type
Topics
1. Introduction
1. Introduction
Add topic from list
Delete selected topic
Save
Cancel

(a)

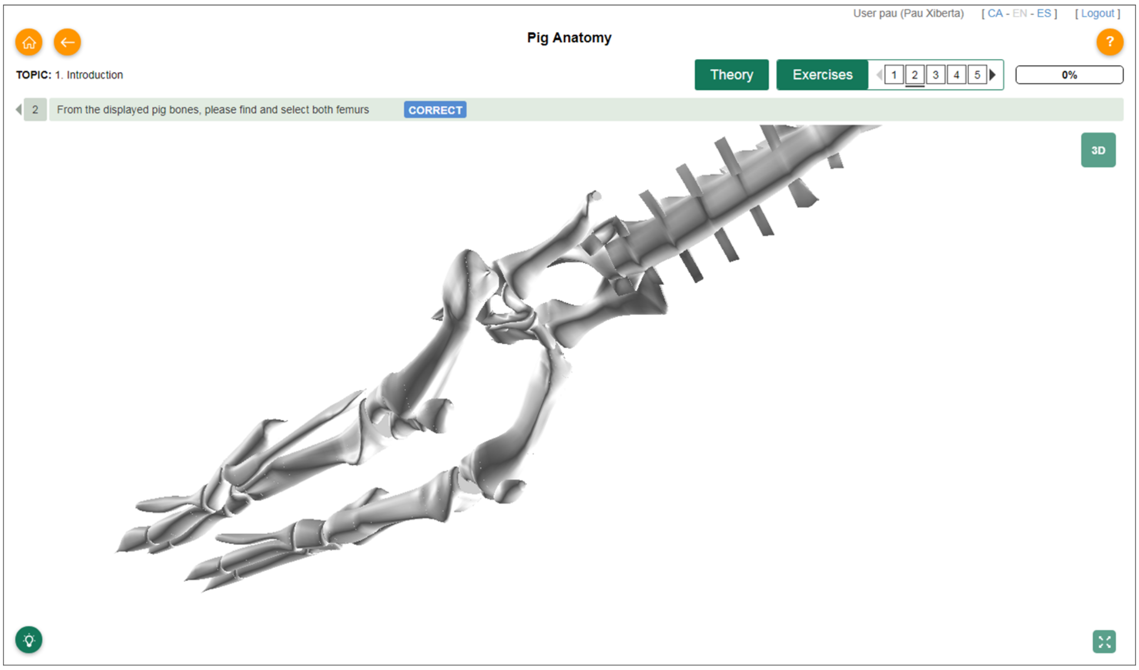

User pau (Pau Xiberta) [CA - EN - ES] [Logout]
Pig Anatomy
TOPIC: 1. Introduction
Theory
Exercises
1
2
3
4
5
0%
1
Please indicate which anatomical part of the pig corresponds to the dark area outlined in the image.
The heart
The lungs
Nothing
The small intestine
CORRECT
2D

(b)

Figure 5.

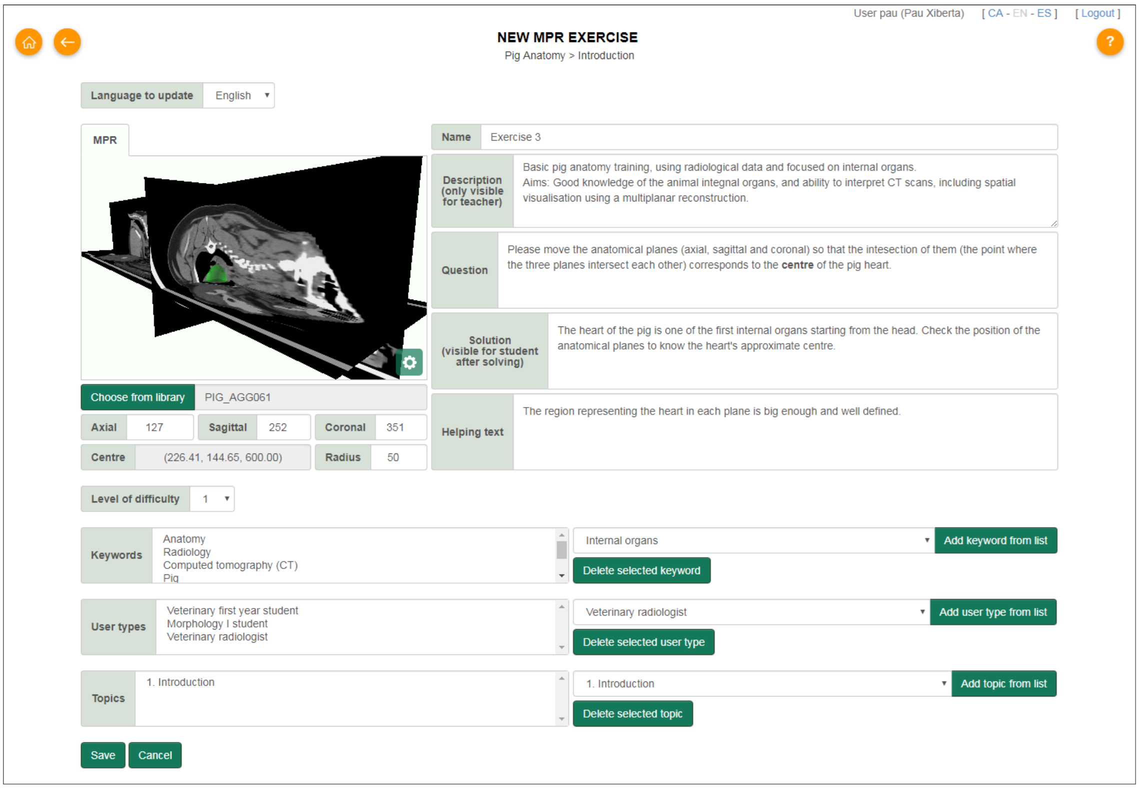

User pau (Pau Xiberta) [CA - EN - ES] [Logout]
NEW 3D LOCATION EXERCISE
Pig Anatomy > Introduction
Language to update
English
3D
Add
Library
Delete
Models
left_femur
Add to solution
Solution models
left_femur
right_femur
Remove
Name
Exercise 2
Description (only visible for teacher)
Basic pig anatomy training, focused on bones.
Aim: Good knowledge of the animal bones.
Question
From the displayed pig bones, please find and select both femurs
Solution (visible for student after solving)
The femurs, or thigh bones, are the most proximal bones of the leg (the closest ones to the hip joint), found only in the hindlimbs.
Helping text
In vertebrates with four legs, the femurs are found only in the hindlimbs.
Level of difficulty
1
Keywords
Anatomy
Pig
Femur
Bones
Bones
Add keyword from list
Delete selected keyword
User types
Veterinary first year student
Morphology I student
Morphology I student
Add user type from list
Delete selected user type
Topics
1. Introduction
1. Introduction
Add topic from list
Delete selected topic
Save
Cancel

(a)


User pau (Pau Xiberta) [CA - EN - ES] [Logout]
Pig Anatomy
TOPIC: 1. Introduction
Theory
Exercises
1 2 3 4 5
0%
2
From the displayed pig bones, please find and select both femurs
CORRECT
3D

(b)

Figure 6.


User pau (Pau Xiberta)
[CA - EN - ES]
[Logout]
NEW MPR EXERCISE
Pig Anatomy > Introduction
Language to update
English
MPR
Name
Exercise 3
Description (only visible for teacher)
Basic pig anatomy training, using radiological data and focused on internal organs.
Aims: Good knowledge of the animal integral organs, and ability to interpret CT scans, including spatial visualisation using a multiplanar reconstruction.
Question
Please move the anatomical planes (axial, sagittal and coronal) so that the intesection of them (the point where the three planes intersect each other) corresponds to the **centre** of the pig heart.
Solution (visible for student after solving)
The heart of the pig is one of the first internal organs starting from the head. Check the position of the anatomical planes to know the heart's approximate centre.
Helping text
The region representing the heart in each plane is big enough and well defined.
Choose from library
PIG_AGG061
Axial
127
Sagittal
252
Coronal
351
Centre
(226.41, 144.65, 600.00)
Radius
50
Level of difficulty
1
Keywords
Anatomy
Radiology
Computed tomography (CT)
Pig
Internal organs
Add keyword from list
Delete selected keyword
User types
Veterinary first year student
Morphology I student
Veterinary radiologist
Veterinary radiologist
Add user type from list
Delete selected user type
Topics
1. Introduction
1. Introduction
Add topic from list
Delete selected topic
Save
Cancel

(a)


User pau (Pau Xiberta)
[CA - EN - ES]
[Logout]
Pig Anatomy
TOPIC: 1. Introduction
Theory
Exercises
1 2 3 4 5
0%
3
Please move the anatomical planes (axial, sagittal and coronal) so that the intersection of them (the point where the three planes intersect each other) corresponds to the **centre** of the pig heart.
CORRECT
MPR

(b)

Figure captions

Figure 1. The main modules of the IVET platform and the functionalities provided to teachers and students.

Figure 2. The five steps of the segmentation pipeline used to create a three-dimensional surface model with the CMISS software: (a) input computed tomography scans; (b) selection and connection of nodes to obtain the exterior faces of the model; (c) conversion from the linear model to a cubic model; (d) optional model post-processing; and (e) conversion to the JSON format.

Figure 3. Interfaces of the IVET platform corresponding to (a) the theory editor used by the teachers to create theoretical content, and (b) the theory viewer used by the students to visualize this content. Both interfaces include functionalities to manipulate and interact with two-dimensional (**2D**) images and three-dimensional (**3D**) representations.

Figure 4. Interfaces of the IVET platform corresponding to (a) the exercise editor used by the teachers to create test exercises, and (b) the exercise viewer used by the students to solve test exercises. Both interfaces include functionalities to manipulate and interact with two-dimensional (**2D**) images and three-dimensional (**3D**) models, which can be relevant to solve the exercise.

Figure 5. Interfaces of the IVET platform corresponding to (a) the exercise editor used by the teachers to create three-dimensional (**3D**) location exercises, and (b) the exercise viewer used by the students to solve 3D location exercises. Both interfaces include functionalities to manipulate and interact with the 3D models to enter the answer.

Figure 6. Interfaces of the IVET platform corresponding to (a) the exercise editor used by the teachers to create exercises which require the use of the multiplanar

reconstruction (**MPR**) visualization, and (b) the exercise viewer used by the students to solve MPR exercises. Both interfaces include functionalities to manipulate and interact with the anatomical planes.