Teaching Image Processing and Visualization Principles to Medicine Students

Christina Gillmann* University of Kaiserslautern
Thomas Wischgoll† Wright State University
Jose Tiberio Hernandez‡ University of Los Andes
Hans Hagen§ University of Kaiserslautern

Abstract

Although image processing becomes increasingly important in most applications such as medicine, image processing and visualization is usually not a part of the medical education and therefore not widely spread in clinical daily routine. Contrary to students from computer science, medical students are usually not familiar to computational models or algorithms and require a different view of the algorithms instead of knowing each computational detail. To solve this problem this paper presents the concept of a course that aims to impart image processing and visualization principals for students in medicine in order to pioneer a higher acceptance and propagation of image processing techniques in clinical daily routine.

Keywords: Teaching of Image Processing and Visualization, Dialogic Learning

1 Introduction

The field of image processing and visualization is a wide topic and constantly increasing since decades [3]. This results in a large variety of novel techniques that are capable of increasing the quality in medical image processing and raising the potential to improve clinical daily routine tasks. Contrary to this trend, clinical daily routine is still dominated by classical image processing and reviewing methods such as slice-by-slice reviewing of multi-slice scans, where doctors scroll through the different slices of a scan while solely reviewing a single slice at a time [10].

This observation has different origins. On the one hand novel scientific methods are often prototypes that form a proof of concepts but are still far away from being suitable to be used in clinical daily routine [5]. On the other hand, medical doctors education does not cover the topics of image processing and visualization. This results in the problem, that medical researchers are very unfamiliar with these methods.As their decisions can have a huge impact of patients life, experiments are not conducted in clinical daily routine and medical doctors usually continue using the image processing methods they have learned throughout their education [11]. Moreover, medical doctors tend to get used to these methods and become very conservative in order to learn novel techniques [6].

To solve this problem, this paper presents the concept of a course to teach image processing and visualization techniques to medicine students. Therefore, the concept of Dialogic learning [14] is utilized , which is a collaborative learning model. During the lectures, the teacher is introducing the core ideas of the image processing concepts. The students use these concepts and apply them to datasets from their field to obtain a feeling how to apply these techniques and what their advantages and drawbacks are. In a final group project smaller groups of students have to solve a specific task based on a selected dataset as well as document and present their results through a short paper and poster.

With the proposed concept this paper contributes:

- A didactic concept to teach computer science concepts to medical students
- A collaborative course style to teach through practical examples

The lecture can be included into medicine studies in its presented form or can be utilized to teach image processing and visualization techniques to students from not computer scientist related studies while exchanging the utilized datasets.

2 Goals of this course

When teaching image processing and visualization principles the focus usually lies on the impart of mathematical concepts and their implementation. Contrary to this group medical doctors approach this topic from a customer point of view. They require to know in which cases they can make use of different techniques and which advantages and drawbacks they have. Medical doctors do not require to know how exactly the algorithms works, but they need to know, what they do, when they can be used and what the limits of the different approaches are. Therefore, we can define four main goals for the presented course:

Introduction of basic principal computer science concepts and workflows The medical education focusses on the impart of anatomical concepts, diagnosis, surgery routines and ethical questions, whereas the computer science education is focussing on the question how to describe and proceed data. Therefore, the first goal in teaching image processing concepts to medical students is to introduce the basic idea of data processing especially in the case of medical image data.

Introduction of image processing and visualization principles The core concept of image processing and visualization is the image processing pipeline [12]. Therefore, one goal is to form the knowledge on the basic image processing pipeline steps, their definition, tasks and their relation to clinical daily routine compared to the state of the art techniques.

Shaping of basic intuition to rate the possibilities and limits of image processing techniques For each image processing step, there exist a variety of techniques that can be used to solve a specific task. These methods differ in their number of input parameters, strengths and weaknesses, and resource efficiency. The presented course targets to teach these aspects and show medicine students in which cases these methods can be utilized and what their output means.

Equip medical student with the knowledge to design individual image processing workflows The image processing pipeline is not a fixed setup. Steps can be switched, duplicated or exchanged by different techniques. This course targets to equip medical students with the knowledge on how to build different image processing pipelines according to a given task in order to obtain suitable results.

*c_gillma@cs.uni-kl.de
†thomas.wischgoll@wright.edu
‡josetiberio.hernandez@gmail.com
§hagen@cs.uni-kl.de

3 TEACHING CONCEPT

The following section will summarize the organization, the pedagogic concept and the grading process of the lecture image processing and visualization concepts for medicine students, as well as the application of the presented course to different study plans.

3.1 Organization

The cousre presented in this paper is based on the european grading system, that is a standard describing the time consumption of a course. Therefore, a course obtains a specific amount of ECTS (European Credit Transfer and Accumulation System) [1]. The standard requires, that each ECTS point refers to 35 - 40 hours of work for the student. This can be work of any kind, covering lectures and exercises, projects, lecture and exam preparations, or paper work. The lecture image processing and visualization principles for medicine students is designed to consume 4 ECTS points, which transfers to a total amount of 100 - 120 work hours in total.

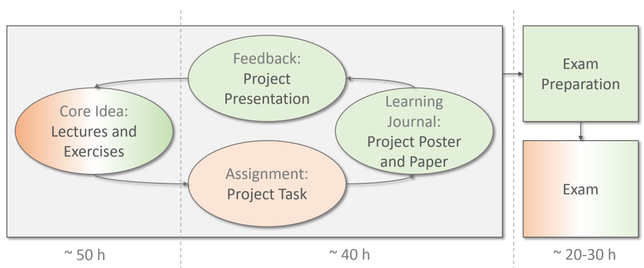

Figure 1: Overview of course compartments and the planned time consumption for each part. The colors indicate if the compartments are conducted under the teachers advisement (red) or conducted by the students (green).

Figure 1 presents a graph of the general course design. As it can be seen, the course consists of 3 major parts: lectures and exercises, project preparation and its presentation, and the exam with its preparation. The lectures and exercises will require an approximate time consumption of about 50 hours including lecture and exercise preparations by the students. The student project requires 40 hours of work including project work, preparation of the poster presentation and writing of a short paper summarizing the group work and results. Finally, the exam preparation will take about 20 to 30 hours of work from the student. This amount of time is hard to estimate, as this is highly depending on the student, his capacities and his level of involvement throughout the lecture.

3.2 Pedagogic Concept

The pedagogic concept behind the lecture image processing and visualization for medicine students is based on the theory of **dialogic learning** [14]. The concept consists of 4 steps: core idea, project, learning journal and feedback.

Figure 1 shows an overview of the dialogic learning concept and how it is implemented in the presented course. The concept starts with a presentation of the *core idea*, in our case the image processing pipeline and their compartments which are presented using lectures and exercises. This is followed by a *project assignment* where small groups of students obtain the task to design an image processing pipeline for a specific clinical scenario based on the learned concepts of the lecture. At the end of the project assignment each group has to present their results by handing in a short paper on how they designed their image processing pipeline. In dialogic learning theory this part is called the *learning journal*. The purpose of this journal is to help students relate their experiences with the new learned concepts. Finally, the students have to present their results during a poster presentation. This is called the *feedback* step of dialogic learning and helps express students their point of view of the learned topics.

3.2.1 Lectures and Exercises

Although the goal of the presented course is to teach image processing and visualization principles without reaching the implementation level, some terms and computer science concepts need to be discussed in the lecture. This has two reason. First, no algorithm can be utilized properly without at least a basic knowledge about the mathematical concept behind it. Second, misscommunication between medical doctors and computer scientists origin from both parties being unable to speak or understand the opposit's language. In order to solve this issues major computer scientists concepts are taught during the lectures.

As a semester usually consists about 12 weeks, the presented course is planned for this time range. In each week, there will be two lecture slots, each consisting of 90 minutes. One of the slots is a lecture where the teacher presents the core ideas of the lecture and the second slot is a classroom exercise used to repeat and demonstrate the learned topics from the lecture. Table 1 shows which topics are covered in the lectures and exercises during the different weeks. As it can be seen in the table, solely 8 of the 12 weeks are required to complete the content of the presented lecture. As mentioned before, a part of the pedagogic concept contains a student project. Therefore, the remaining lectures are used to conduct a supervised student project. The details for this project can be found in Section 3.2.2.

Week	Lecture Topic	Laboratory
1	Introduction to the course	Analysis of clinical daily routine
2	Introduction to Images [1]	Images and their problems
3	Volume rendering [4]	Introduction to Voreen [9]
4	Overview image processing pipeline	Introduction to ParaView [2, 13]
5	Image Enhancement [15]	Apply different functions to real datasets
6	Image Segmentation [16]	Apply different algorithms to real datasets
7	Introduction to geometry	Modeling shapes from real datasets
8	Geometry extraction [7, 8]	Apply different algorithms to real datasets

Table 1: Lectures and corresponding exercise topics of the presented course enumerated by the week.

The topics of the lecture are designed to offer a suitable overview of the state of the art in image processing. The course starts with an general introduction of the course containing an analysis why image processing is required in various fields and how different applications can benefit from image processing techniques. During the corresponding exercise the goal is to analyze the workflow in clinical daily routine, where images are required and how image processing can be beneficial in these special cases. Students are highly encouraged to propose scenarios they are interested to discuss during the lecture.

The second lecture targets the mathematical description of images. The lecture aims to introduce basic terms and mathematics of images, as pixels and their sizes. The image generation process itself and most occurring sources of image errors will be explained as well. The corresponding exercise targets to apply this knowledge to clinical datasets.

[1] http://ec.europa.eu/education/ects/users-guide/index_en.htm

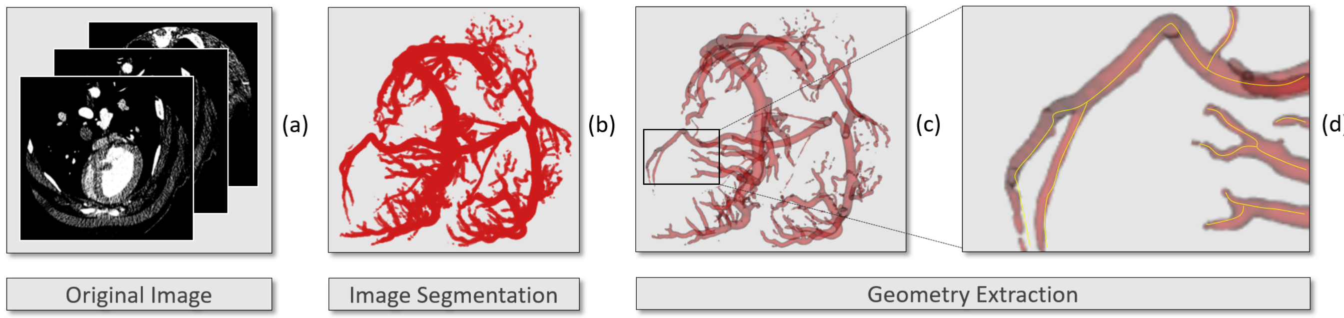

Figure 2: Example result of a student project. Original image (a) and its segmentation output (b). Based on the segmentation output isosurfaces (c) and centerlines (d) can be computed.

While collaborating with people from medicine in can be experienced that they are very upstaged about volume rendering techniques [6]. The presented lecture is a suitable place to gain tolerance in the early stage of the medicine education. Therefore, the third lecture's topic is volume rendering. During the lecture the concepts of transfer functions and different 3D navigation techniques will be discussed, whereas during the exercise the students have to apply these methods to medical datasets. This will be achieved by introducing the students to the Voreen software [9]. The software is modular and suitable to explore different volume rendering techniques without requiring writing code.

In the forth lecture, the focus lies on the introduction of the image processing pipeline. Therefore, the different steps of the pipeline will be explained and examples will be shown. During the corresponding exercise the students will be introduced to the software used in the following weeks of the lecture. As mentioned before medicine students are not familiar with computer science concepts and in most cases they are not able to generate their own code. Considering the time that is available for the presented course it is not possible to teach the students the required knowledge to implement algorithms. To avoid this problem we designed a laboratory setup for the students where they can make use of the already implemented algorithms and apply them to different datasets and combine different techniques to generate entire image processing pipelines. The used framework is based on ParaView [2, 13] as it can be used out of the box and does not require self made code. The software is installed in the laboratory the exercise takes place and the forth exercise will be used to introduce student to this software.

Starting from the fifth lecture, each lecture will discuss one step of the image processing pipeline in the order image enhancement, image segmentation and geometry extraction. In each lecture the state of the art methods for each step will be discussed. The goal for this lectures is not to go into implementation details. In contrast to that, the focus lies on how to use these methods, which parameters are required, what these parameters mean, which advantages and drawbacks each of these techniques have and in which cases they work and in which they may output wrong results. The corresponding exercises are used to give the students the opportunity to discover the mentioned methods from the lecture. They are encouraged to try different datasets and review the output of the algorithm. In addition the influence of input parameters has to be tested by the students. This should give the students a general impression how to work with the mentioned algorithms and what are important aspects to focus on while working with these algorithms.

The seventh lecture is an exception in this row. Before teaching the concepts of geometry extraction we first want to teach the basics about how geometry is used in the computer science community and show which geometries are important in the medical applications. In this lecture we focus on iso-surfaces and centerlines as they are most common in the medical area. The corresponding exercise gives the students the opportunity to extract their own geometries based on medical image data and learn which properties they have.

In general, the hand in of the exercise is mandatory. Although we cannot force students to attend the lectures and exercises we require them to hand in all exercises and complete a minimum of 50 % of each. This requirement needs to be fulfilled to be able in participating in the group project and to obtain an appointment for for an exam. This requirement is a save mechanism for students to avoid that they try to complete the project and the exam without having enough knowledge to pass them.

3.2.2 Student Project

As Table 1 show, the lecture solely require 8 of the 12 weeks that are available for the course. As mentioned in Section 3.2 the presented lecture is based on the concept of dialogic learning. After the core ideas of the lecture where presented and repeated during the exercises the goal of this lecture is to encourage students to implement their own image processing pipelines while solving a given task.

Therefore, the students are divided into groups of 4 to 5 people. Each group obtains a dataset with a specific task. This task can for example be: Create an image processing pipeline based on a computed tomography scan of the heart that is able to output the geometry of the coronary system.

While solving this task, the students have to process the entire image processing pipeline they have learning during the lectures. The important aspect in this task is not to obtain the perfect result. Instead, it is important that the students can explain the choices they made in the design process of their image processing pipeline. Each step requires a documentation summarizing their reasoning of the algorithm choice for the specific task. In addition to that a list of possible problems or risks resulting from their algorithm choice is required.

While working on the project, the students can present their intermediate results, ask questions and work supervised during the times that are blocked for the lectures and exercises. Still, the supervisor is not giving directions or suggestions. His task is to answer questions and help during technical or organizational questions.

3.2.3 Project Presentation

In the last week of the course each group has to present their results of their individual task as we believe that this is one of the lecture's aspects the students benefit most from. All students are required to attend. Each group has to submit a short paper summarizing their result including a summary of all methods used in their pipeline, a reasoning why they chose these methods, remaining risks, and images of their results. Besides the paper, each group has to design a paper presenting the results of their group work. During the presentation day each group explains their image processing pipeline design and results to the other groups. The resulting poster will be used as handouts for all students to help them record the results of the course and preparation for the exam.

Figure 2 shows an example result of a student project. The original image was obtained by an animal experiment showing the heart of a dead pig. The images where in a very good condition thus the students decided that the image enhancement step is not required in this case. Based on the images they performed a segmentation of the coronary artery system using a seed based segmentation algorithm. Resulting from this segmentation the group extracted the surface of the coronary tree by using the marching cubes algorithm and finally extract a centerline using a thinning approach.

While a group is presenting their results, the remaining groups can ask questions or start discussions about the pipeline choices the presenting group made. The teacher's task in this discussion is to moderate the discussion or encourage topics he or she thinks that are important to discuss about.

At the end of the group project the teacher assigns a grade to each group based on the presentation and on the paper the groups handed in.

3.3 Exam, Preparation and Grading

After the lectures and student projects are finished, the students can start to prepare themselves for their exam. The exams are oral and will take about 30 Minutes. Contents of the exam are all topics that have been discussed during the lectures, exercises and in the student project. The results of the group projects are explicitly included in the content of the oral exam.

To prepare themselves, the students can use the lecture and exercise notes as well as the handouts of the project presentations.

In the first 10 minutes of the exam, the examiner will ask general questions about the image processing pipeline and the foundations that have been discussed during the lecture. In the remaining 20 minutes, the examiner will hand out a dataset and a task to the student. For this task the student has to describe briefly how he will approach this problem using image processing methods. To finish this task successfully, the student has to give reasons why he would choose a specific technique or skip image processing steps.

The final grading of the course is a mixed grade consisting 50 % of the results of the student project and 50 % of the performance in the exam. Criteria for a good exam performance are a good reasoning for the algorithm choices of the student, as well as a structured presentation of his solution following the learning image processing pipeline.

4 Target group and studies

The presented concept is planned to be part of the distance learning master degree [2]medical physics, which is available at the Univeristy of Kaiserslautern.

In addition, the course can be offered to further studies besides medicine. In particular it is planned as a renewed concept for computergraphics for students of others majors [3], which is a lecture designed to offer computer graphics principles to non-computer scientists. The current course targets rendering, but origins from several years ago where visual systems ehere not wide spread in application domains. Although various groups of students besides medicine can participate in this course, the proposed concept is still suitable for them. Students from different majors often face the problem, that computer science concepts are unknown to them, but often required and used in their domain. Attending the presented course of this lecture aims to strength their ability to utilize image processing and visualization techniques to solve3 their daily tasks more efficiently.

[2]https:\\www.zfuw.uni-kl.de\en\distance-learning-courses\science-engineering/medical-physics\

[3]http:\\www-hagen.cs.uni-kl.de\?page_id=29

5 Conclusion and Future Work

This paper presents the concept of a course design to teach image processing and visualization principles to medicine students while regarding their special background and interests. Therefore, as the pedagogic concept dialogic learning is used to introduce principal computer science concepts, image processing and visualization principles, shape a basic intuition to rate the possibilities and limits of image processing techniques and workflows, and equip medical student with the knowledge to design individual image processing workflows.

As a future work we are planning to setup a further course targeting both, medicine and computer science students and bring them together to learn from each other and discuss ideas.

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