A DESIGN-IMPLEMENT EXPERIENCE WITHIN COMPUTER VISION

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ABSTRACT

A design-implement experience in computer vision, which is part of the Bachelor's program in Artificial Intelligence at the Federal University of Goiás, Brazil, is presented. The program runs over four years, and the design-implement experience is part of a course module in computer vision in the third year. The first years of the program contains mandatory course modules in mathematics, computer science and entrepreneurship, and the module in computer vision is the first module where students were introduced to work in projects in the CDIO form. As a result, some of the students which had previous knowledge about project management and development performed well and achieved solid results. Some other students which underestimated the project scope had a less solid performance and achieved weaker results. However, the final overall feedback from the students was positive and lessons learned were appointed for future improvements.

KEYWORDS

Design-implement experience, computer vision, project-based learning, Standards: 2, 4, 5, 11

INTRODUCTION

In recent years, universities and research institutions all over the world have showed increasing interest in the assessment and improvement of the quality of higher education. The CDIO initiative is one of the efforts that have received the most attention all over the world, as demonstrated by the amount and quality of the universities that have subscribed to it, to name a few, MIT in the US, and KTH in Sweden. The impact of the CDIO initiative has more recently been extended further to universities in Brazil. More specifically, the Federal University of Goiás (UFG) has recently implemented with a CDIO design-implement experience in one of their programs. The effort was made possible due to a close bilateral collaboration between scholars from Sweden (Linkoping University) and Brazil (Federal University of Goiás).
The purpose of this work is to present the results of the implementation of a CDIO design-implement experience in computer vision within the Bachelor's program in Artificial Intelligence at the Federal University of Goiás. The CDIO experience was implemented and completed on a full semester during 2022 and 2023, and it is the first experience on its class to be performed

at UFG. Numerous examples of design-implement experiences have been reported within the CDIO community, and one example is reported in Svensson and Gunnarsson (2012). Also, the CDIO Knowledge library, that is reached via the CDIO web site, contains many examples of such learning activities. Even though the examples of design-implement experiences cover a wide range of disciplines there are very few published examples within the CDIO community related to the computer vision field. Areas somewhat related to computer vision are treated in, for example, Bermejo et.al (2016) and Var Torre and Verhaevert (2017). Hence, to the best of the authors' knowledge no works have been reported within the CDIO community related to computer vision and, thus, the novelty of our contribution. Even though it has not been reported in the literature, the course Images and Graphics Project Course CDIO (2023), given at Linköping University, is an excellent example of a course within computer vision designed according to the CDIO framework.

BACKGROUND INFORMATION

The CDIO framework

The fundamental aim of the CDIO framework is to educate students who are "ready to engineer" and to raise the quality of engineering programs, see Crawley et al. (2014) and the web site CDIO Initiative (2023). The framework relies on four key components:

- A "definition" of the role of an engineer.
- Clearly defined and documented goals for the desired knowledge and skills of an engineer listed in the document CDIO Syllabus (2023), which serves as a specification of learning outcomes.
- Clearly defined and documented goals for the properties of the engineering education program collected in the document CDIO Standards (2021), which works as guidelines of how to design a well-functioning engineering education.
- Methods and tools for systematic development and management of education programs.

According to the CDIO framework, see Crawley et. al. (2014) page 50, the goal of engineering education is that every graduating engineer should be able to *Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.* This formulation can serve as a definition providing the basis for the entire CDIO framework. Adopting the definition, it is natural to design and run an engineering education program with this in focus. The CDIO Syllabus is a list of the desired knowledge and skills of a graduated engineer. The document can be found via the CDIO web site, and it consists of the following four main sections:

1. Disciplinary knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: Teamwork and communication
4. Conceiving, designing, implementing, and operating systems in the enterprise, societal, and environmental context – The innovation process.

Via the sub-sections and sub-sub-sections, the document offers an extensive list of knowledge and skills, which can be used to specify learning outcomes of individual courses or education programs. The CDIO Standards (2023), which also can be found and explained in detail via the CDIO web site, is a set of twelve components that are necessary for designing and running an engineering program that enables the students to reach the desired knowledge and skills. The CDIO framework offers a variety of tools for development and management of education programs, including for example the so-called Black-box exercise and the CDIO Syllabus survey. These tools are described in some detail in Crawley et al (2014).

CDIO in Brazil

The CDIO framework has received considerable attention in Brazil, and several universities have joined the CDIO Initiative. Also, several papers describing the implementation of the CDIO framework in the Brazilian context have been published. See, for example, Lourenco and Veraldo (2015), Neto et al (2019), Passos et al (2019), and Rezende et al (2022). As pointed out in Rezende et al (2022) the CDIO framework is very valuable in the process of implementing the new national guidelines for engineering education.

THE CONTEXT OF THE DESIGN-IMPLEMENT EXPERIENCE

The Federal University of Goiás

The Federal University of Goiás (UFG) is a public research institution located in Goiania, state of Goiás, Brazil. It is the largest university in the Central-West region in Brazil, immersed in a socioeconomical environment characterized by a strong agro-industrial ecosystem. With 59 years of history, UFG has 104 undergraduate schools, 78 post-graduate programs, with approximate 22,000 students distributed across four campuses. The Bachelor's program in Artificial Intelligence, where the module in computer vision belongs to, is run by the Institute of Informatics at UFG, in addition to the three other Bachelor's programs Computer Science, Software Engineering, and Information Systems.

The Bachelor's Program in Artificial Intelligence

The Bachelor's program in Artificial Intelligence, commonly shortened as BIA from its acronym "*Bacharelado em Inteligência Artificial*" in Portuguese, is the first program of its class in Brazil and the newest undergraduate program offered by the Institute of Informatics at UFG. The program begun activities in 2020 with the purpose of fulfilling the lack of professionals in artificial intelligence in the local Brazilian market. The admission system of BIA allows 40 new students each year, with an entrance examination at the beginning of every year. The BIA program has currently three ongoing classes and an expected date of graduation for the oldest class by the end of 2023. BIA is a four-year program, composed of eight semesters and 3,200 hours of credits in total. The first two years include course modules on mathematics, computer science and entrepreneurship. The last two years contemplate introductory, intermediate, and advanced courses on machine learning, deep learning and their applications in natural language processing, reinforcement learning and robotics, finishing with a pre-professional internship on the last semester at the Center of Excellence in Artificial Intelligence – CEIA (2023) as a part of the requirements for graduation. The computer vision module runs on the fifth semester. It has 64 hours of credits in total and it is the first course of BIA where a CDIO design-implement experience is introduced.

THE DESIGN-IMPLEMENT EXPERIENCE IN COMPUTER VISION

Structure of the course module and learning goals

The computer vision module runs over 16 weeks and corresponds to approximately 3 ECTS credits (60 ECTS credits correspond to one year of full-time studies), which means the students are expected to spend 64 hours on the module.

The learning outcomes contained goals related to (unsupervised) description of a computer vision solution, (supervised) step-by-step implementation of a computer vision algorithm, and the (following-instructions) design of a computer vision system. Here the expressions unsupervised, supervised, and following-instructions refer to the three levels of independence of a student towards reaching the goals specified in the course's Study Plan.

In the first eleven weeks of the module the students receive lectures involving theoretical and practical aspects of computer vision. During these weeks, the students are evaluated on the unsupervised and supervised learning outcomes. The practical activities are designed to be performed in teams and such teams are previously defined on the first week of the course.

The last five weeks of the module are dedicated to the development of the CDIO design-implement experience. The following-instructions learning goal is covered on this step. Five projects are suggested to the students considering applied computer vision tasks, such as 3D-reconstruction, visual odometry and object detection. The teams receive instructions related to the details of the deliverables and their outcomes a week in advance. The project concludes with a written report, an oral presentation and the discussion of the lessons learned from the execution of the project.

Work process and assessment

Twenty-five students took part in the course. They were divided into five teams, with five students in each team. The students were free to choose who to work with and each team had a leader in charge of handling the general team management and communication with the instructor. The tasks were formulated to be developed in five weeks including three incremental work submissions through the GitHub's versioning system. The design-implement experience is evaluated progressively along each submission. The final assessment is done via a written technical report, an oral presentation, and a discussion of the results. Each team have access to some amount of support and supervision during the project's lifecycle. At the end, three teams are randomly selected to participate in a focus group to collect oral feedback from the students about the realization of the design-built experience. The meetings are conducted individually with each group with the aim to reduce cross-feedback biases. The feedback is collected from the leader of each group, who is in charge of collecting the group's feedback previous to the encounter.

Examples of project tasks and results

The teams were attributed five projects of similar workload, including 3D reconstruction, object detection, classification of falls, visual odometry and hand-gesture recognition. Some important observations were identified at the completion of the projects regarding the level of the outcome achieved. The teams who had higher maturity and previous experiences in project development were able to reach the project goals to the point of including additional features and project extensions.

A first team, involved in the fall detection task, chose such topic because it was part of a capstone project they were developing in parallel. Due to this, the participants had already some amount of intimacy with the topic and experience with the type of results they should expect, as they run preliminary tests in advance. With this in consideration, the definition of project tasks and scope were clearer from the kickoff and the team's effort was put on outreaching the original project outcomes by using the capstone project as a benchmark to improve the accuracy of the fall detection task.

A second team, which worked with the hand gesture recognition project, chose such topic because parts of the members were already involved in a robotics challenge of similar scope that was led by Pequi Mecânico, the Robotics group at UFG (2023). In such a case, the team's effort was put on leveraging the team's knowledge in more advanced tasks demanded by the former challenge, such as objection detection and recognition of visual features from the hand. The project tasks and outcome were only well understood by part of students who were already involved in the robotics challenge. This resulted in a heterogenous knowledge about the project goals between the team members and, thus, the learning outcomes achieved individually were diverse as well. The team started with a good performance and motivation, but soon found insufficient time and internal support from the members with less confidence about the topic to be able to surpass the hardest tasks. As a result, part of the team members showed an excellent performance during the oral discussion, whilst some others showed just fair or weak contributions.

A third team, which developed the 3-D reconstruction task, underestimated the scope of the activities. This was mainly due to an excess of confidence about the task, which they considered to be sufficiently easy a priori. As a result, the team was able to technically describe the methodology towards solving a reconstruction task but was unable to complete it due to foundational difficulties found during the implementation, such as implementing a successful outlier rejection strategy, and other more advanced steps.

In summary, the performance of the designed-implement experience of the computer vision class was satisfactory and diverse. The level of performance of the students much depended on hard skills already incorporated by the team members, such as the level of technical expertise about the topic, but also depended on soft skills, such as good project management abilities. This is a result that can be improved on a next run of the course module, for instance, by showing the results from previous CDIO projects to the next classes from the beginning of activities, and by using the practical hours worked at the first weeks of the module to strengthen the hard and soft skills required to achieve a successful design-build experience.

Observations and student feedback

Some interesting observations and lessons learned can be summarized after the learning activity:

- The amount of proper weekly follow-up from the instructor was restricted, mainly because of limited resources in terms of availability of teaching assistants for extra class support.
- Another observation was that teams that were more cohesive also achieved more mature results. Such teams applied a key strategy, which was establishing connections with other related projects they were conducting in parallel. When the level of understanding of the topic was homogeneous, the results were more profound, otherwise, mixed results were achieved when only part of the team members showed a proper understanding of the project tasks they were involved with.
- A third observation was the difference in the level of maturity achieved by the teams at the completion of each project. Some of the teams underestimated the challenges they were given. Therefore, the successful performance of the steps to solve the problem was harder than they expected. This led to a progressive lack of motivation and, therefore, weak results at the end. On the contrary, teams that had some previous knowledge about the topic made a clearer identification of the challenges to be solved and were able to successfully complete the experience on time.

Despite the difference in the performance of the teams, the overall feedback from the students was positive. According to the students, the highlights from the design-implement experience included:

1. Validating the theory in practice.
2. The opportunity to run a computer vision project according to their own interests.

The conclusion from the students was that the CDIO design-implement experience helped them not only to increase their technical level of maturity, which is a pre-requisite of the course module in computer vision, but also to put project management skills in practice, such as schedule planning, a weekly assessment of activities, and the capacity to operate with a limited budget of time and resources.

CONCLUSIONS

In this work we described a CDIO design-implement experience within computer vision at the Bachelor's program in Artificial Intelligence, Federal University of Goiás, Brazil. The results showed that students appreciated the CDIO experience from a professional perspective, highlighting that it helped them to incorporate both the technical maturity required to execute advanced engineering tasks and the project management skills required to succeed on completing the project tasks. In the future, the design-implement experience could be improved with a threefold strategy. Firstly, by showcasing the results from previous classes to newcomers. Secondly, by implementing a teaching assistant support. Thirdly, by extending the CDIO framework to other course modules within the Bachelor's Program in Artificial Intelligence to be able to share and learn from the experiences of other CDIO instructors.

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BIOGRAPHICAL INFORMATION

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