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Hand-drawn animated cartoons for Control Education: insights from the ∞sCaR project ⋆

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Abstract: This paper reports the first results of a series of 2D animated cartoons in Control Education, developed during the project "∞sCaR – 2D Animated Cart∞ns for Control Education Rise". Cartoons can be a powerful tool for enhancing engineering education by making complex concepts more accessible and engaging. The project and results presented in this paper try to exploit those pedagogical advantages in the field of Control engineering education. Feedback from the participants to this project is also proposed, together with promising perspectives for the Control Education community.

Keywords: Control Education, Gamification in Control Education, Diversity and inclusion in Control Education, Systems and Control for societal impact.

1. INTRODUCTION

Increasing the societal impact of Control is one major interest of the Control Education community. Therefore, researchers are more and more interested in developing open-source materials that can be helpful for their colleagues, the students, and general public. The IFAC Technical Committee 9.4 on Control Education offers a solid and suitable framework for such kind of activities, encouraging innovation in Control Education, together with international cooperation and exchange, see the roadmap in Control Education (Rossiter et al., 2023) and strategic directions proposed by (Stapleton et al., 2024).

Several directions/topics in which research has been conducted in recent years cover:

- *First course on Control content*: e.g., syllabus to be taught to undergraduate students having their first Control classes (Rossiter et al., 2019; Vásquez et al., 2019);
- *Teaching online Control courses*: e.g., during the COVID'19 pandemic (Guzmán et al., 2024);
- *Teaching Control for large classes of students*: e.g., large-scale courses in System modeling and Control (Stoica Maniu et al., 2022);

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- *Developing (virtual) laboratories and project-based activities*: e.g., practical experiments (Takács et al., 2023; Bucher et al., 2022; Stoica Maniu et al., 2020);
- *Developing software/toolboxes for Control Education*: e.g., interactive tools to motive students (Rossiter, 2024; Guzmán et al., 2023; Rossiter, 2017; Varga, 2023);
- *Developing repositories for useful Control resources*: e.g., teaching materials to be used during Control classes (Serbezov et al., 2022; Douglas, 2022b);
- *Collaboration with industry*: e.g., motivating students via industrial conferences (Stoica et al., 2023a);
- *Gamification of Control Education*: e.g., developing the escape game CTRL+ESC (Axelson-Fisk et al., 2022), the IFAC Control Calendar (Knorn et al., 2024b), portable games (Gil et al., 2024);
- *Developing outreach activities*: the online "Girls in Control" workshop to introduce the feedback notion to girls allover the world (Jackson et al., 2021; Knorn et al., 2021), onsite Robotics workshops for kids (Stoica et al., 2023b; Bertrand et al., 2024; Hanne et al., 2024), etc.

Gamification in teaching improves students' attention during classes and thus increases their engagement. Several resources have been developed in the last years, for example:

- The IFAC Cartoons distributed with the IFAC Newsletter (Douglas, 2022a);
- The Map of Control Theory, videos and e-books (Douglas, 2018, 2022b);
- Comics on Control Systems (Joshi, 2015);
- The Random Inputs section of the IEEE Control System Magazine proposing cartoons or humorous images Mash (2010), etc.

With the expansion of social media during/after the COVID'19 Pandemics, there is an increase of videos with scientific content, and in particular in Control Education (e.g., see the Youtube channels of (Douglas, 2011), (Bruton, 2011), etc.). Recently, an animated hand-drawn Control cartoon was developed by (Cojan et al., 2024) and served as a proof of concept for developing a series of 2D animated Control cartoons within the ∞sCaR project, as part of the IFAC Technical Committee 9.4 on Control Education.

This paper presents some insights from the ongoing ∞sCaR project, together with the first achievements and current work. The contribution of this paper relies on developing a series of hand-drawn 2D animated Control cartoons by a team of Control specialists together with one 2D animator and one English professor who was an actress at the early stage of her career. The target audience of these cartoons mainly consists of undergraduate engineering students. However, some videos are designed for general public, in order to raise the awareness about the benefits of Control (and Engineering in general).

The remaining part of this paper is structured as follows. Section 2 describes the main features of the ∞sCaR project. Section 3 focuses on the implementation steps. Some examples are given in Section 4, while lessons learned are presented in Section 5. The conclusion and current developments are discussed in Section 6.

2. PROJECT DESCRIPTION

This section details the proposed series of hand-made animated videos, together with the target audience.

In order to motivate undergraduate students and to make them passionate about Control, the Control Engineering community proposes innovative teaching solutions that engage students and align with industrial trends in Control. Comic strips are more and more used to illustrate engineering concepts. However, using animation in education requires the simplification of complex information thereby improving learners' retention and engaging learners. Therefore, the ∞sCaR project aims to create a series of 2D hand-made animated cartoons on Control.

The long-term objectives of this project are to motivate undergraduate students following their first course on Control to choose a future Control engineer career, and, more generally, to show valuable seeds in the heart of young generation to pursue the Control engineering direction. Therefore, most of the videos are designed for undergraduate students. Nevertheless, parts of the videos are dedicated to children and teenagers.

The animated cartoons videos development consider the following elements:

- *Storytelling approach.* Each video presents a scientific concept illustrated by an everyday situation, together with an easy to understand industrial concept.
- *Gamification elements.* Besides these 2D hand-made animated cartoons, interactive challenging quizzes (with several difficulty levels) will be proposed to the learners as a formative assessment.
- *Accessibility and inclusivity aspects.* The videos will be available online, with the possibility to adjust the playback speed. Transcripts and subtitles will be provided.
- *Feedback.* Feedback from the learners will be collected via an online survey.

3. PROJECT IMPLEMENTATION

This section details the main steps of the project implementation.

In order to remain within budget constraints, the project members decided to design in the first stage a series of ten short videos (between two and three minutes each). One of the first question addressed during the project was related to the topics to be considered for each video. As the videos are short, it is important to mainly focus on the Control concepts, while keeping a simple structure, without introducing the mathematical concepts. Therefore, short standalone videos are currently under development. Each video is focusing on one of the following concepts: PID control, predictive control, nonlinear control, learning-based control, state estimation, cooperative control, system modeling (targeting undergraduate students), and feedback concept (targeting the general public). A teaser video will be also proposed.

Each video is designed in two parts.

- First, it presents the main Control notion.
- Second, an industrial or everyday application of the considered notion.

Within a pedagogical context, once the topics of the videos were proposed, the corresponding learning outcomes were defined for each video. To keep the animation simple, offering as much degrees of freedom as possible for the animation, only two characters were considered, with a teacher/learner role or co-learning roles (changing roles). After analyzing different possibilities, two cats were considered for the characters, one called Mia with a feminine voice and one called Max with a masculine voice. The scientific message of the videos is essential and it is important not to distract the learners from the message; therefore, two neutral characters were considered for the animation.

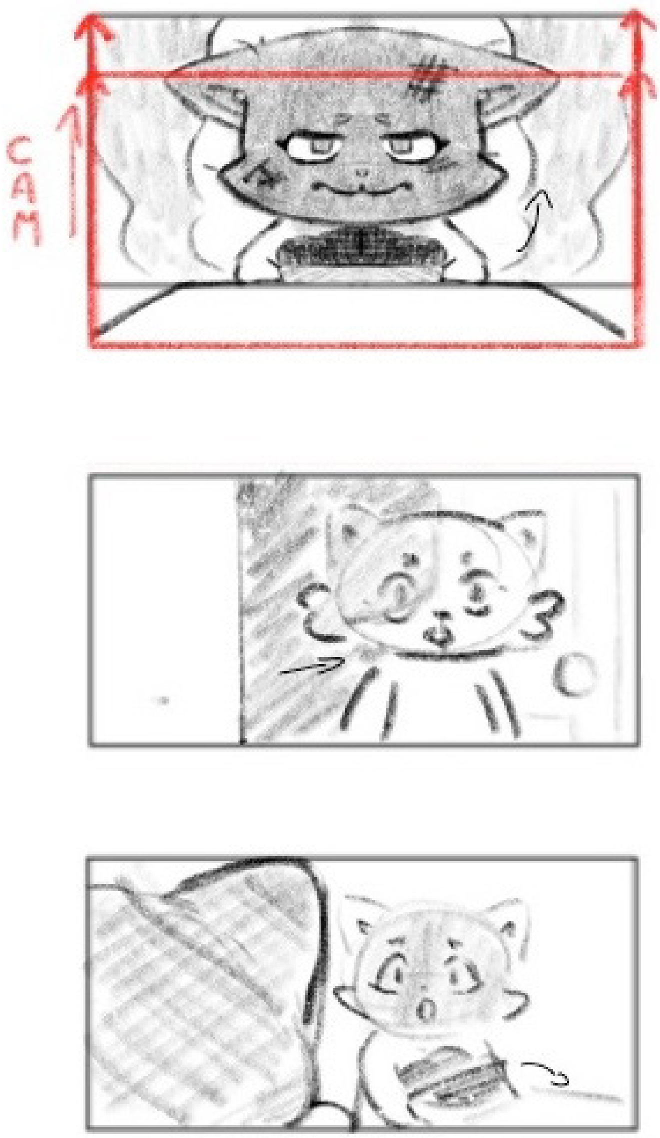
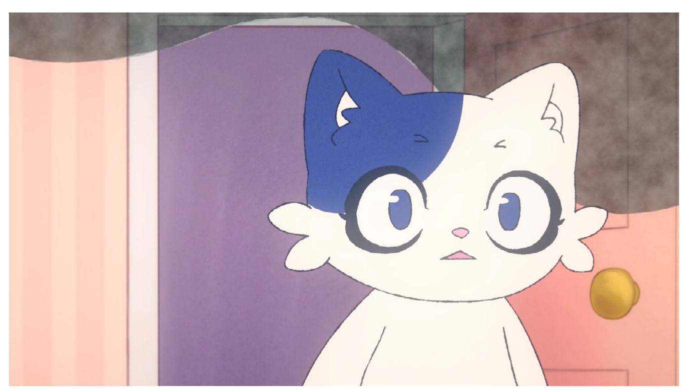


Fig. 1. Extract from the storyboard of the first video.

The following work flow was considered for each video:

- *Video driving person*: For each video, there is one leader who proposes the scenario of the video. In addition to the leader, there are other two or three persons who will review the scenario and give feedback on it.
- *Script*: Each video driving person will write a script, containing information for the voiceover and for the 2D animator.
- *Script review*: The proposed script is reviewed both from the Control point of view and animation.
- *Storyboard*: Once the script is finished, a storyboard is proposed by the 2D animator (see Fig. 1 for an extract of the PID storyboard).
- *Storyboard review*: The storyboard is reviewed by the persons in charge alongside the video.
- *Voiceover recording*: The voice for the two cats are recorded. One additional difficulty is that the two persons recording the voiceover are in different places (Julie in France and Brian in the United States). Therefore, Julie records first her voice, then Brian

(a) Scene 1



(b) Scene 2

(c) Scene 3

Fig. 2. Screenshots from the first video.

records his voice, then he combines the two parts and sends the global voiceover file to the 2D animator.
- *Animation*: The 2D animator proposes a first version for each video, based on the script, the storyboard and the recorded voiceover. Three scenes from the PID animation are depicted in Fig. 2. The reader can see the difference between the storyboard and the scenes used for animation, which contain more details (colors, backgrounds, etc.).
- *Animation review*: Feedback is provided for the animation by all the project participants.
- *Final video*: The final version of the video is signed off and uploaded online, see the first video on the IFAC YouTube channel `https://youtu.be/BiQjCmzFsrU`.

4. ILLUSTRATIVE EXAMPLES

This section briefly summarizes two examples of the first videos developed as part of the project to transmit the basic concepts on PID and predictive control, respectively.

4.1 PID control

To give an idea of the how the scripts of the videos have been conceived, we consider Video 1 related to PID control as an illustrative example. In order to explain what a PID controller is, since this is actually the most employed controller that can be used in a variety of applications, we started with a simple example where a cake is not well cooked in the oven because the temperature is not controlled appropriately. The dialogue between the two cats highlights that a feedback controller can solve the problem and PID control is the most straightforward solution. Then, again through the dialogue between the two cats, the three actions are explained separately, using intuitiveness as much as possible. In particular, it is highlighted that proportional action alone is not capable to achieve a zero steady-state error. Then, the link of the integral action with the past errors and the link of the derivative action with the future errors are underlying, always considering the oven temperature application. In this context the mathematical details are kept to a minimum, exploiting the physical meaning of the integral and derivative of a function. Finally, once the fundamental concepts have been explained, it is mentioned that PID controllers are very widely used in industry and that the tuning of the parameters plays a key role in obtaining the required performance. In this way, it is believed that the student will be motivated to examine the topic in more depth.

4.2 Model Predictive Control

As a second example, the cartoon related to Model Predictive Control (MPC) is considered. The story starts by highlighting that, with respect to PID control, MPC is capable of handling more challenging systems with multiple variables and constraints. Then, the simple and intuitive application of driving a car (where the steering angle and the accelerator throttle are the manipulated variables) is the matter of discussion of the two cats. In simple terms, the main idea that is conveyed is that it is better to anticipate the future (by looking through the windscreen), as MPC does, rather than reacting to the past (by looking at the rear-view mirror), as a standard feedback controller does. Then, the trade-off between performance and control effort is introduced by considering that, in order to get very fast acceleration, we need very large throttle movements which uses a lot of fuel. As for the wider use of MPC control, it is finally stated that there are a lot of industrial applications for such a kind of control approach and this should indeed motivate students to study the topic more in detail (for example by understanding how a model can be obtained and used in order to optimize the control action).

5. LESSONS LEARNED

The development of the ∞sCaR project has provided valuable insights into the use of 2D animated cartoons for Control Education, highlighting key aspects of storytelling, collaboration, accessibility, and engagement.

5.1 Good practice

One of the most significant takeaways is the effectiveness of storytelling in simplifying complex concepts while maintaining student engagement. By linking theoretical notions to real-world applications, students found the material more relatable and easier to grasp. However, achieving the right balance between educational depth and accessibility proved challenging. Ensuring technical accuracy while avoiding unnecessary complexity required an iterative feedback process involving both educators and animators to refine content and maintain clarity.

Another critical lesson concerns the interdisciplinary collaboration required for such a project. The involvement of educators, animators, and voice actors necessitated a structured workflow for scriptwriting, storyboard design, and animation production. Budget and time constraints underscored the importance of streamlined procedures and effective communication among team members. Moreover, early feedback from students and educators indicated a strong interest in interactive elements, such as quizzes, to reinforce learning outcomes. Future developments will, therefore, focus on expanding interactivity, broadening the range of topics, and optimising animation production for improved efficiency and pedagogical impact.

Character design and voice acting also emerged as essential factors in enhancing engagement and learning outcomes. The decision to use two neutral cat characters allowed for a relatable yet non-distracting presentation of control concepts. Viewer feedback highlighted the importance of voice modulation, pacing, and dialogue style in maintaining attention and reinforcing key ideas. Additionally, accessibility considerations – such as subtitles and transcript availability – proved crucial in ensuring inclusivity, allowing a more diverse audience to benefit from the content. These findings suggest that future Control Education initiatives could further explore the role of visual and auditory elements in optimising student comprehension and motivation.

5.2 Enhanced educational impact

Beyond the technical challenges and workflow improvements identified during the project, the ∞sCaR initiative has provided important insights into its broader educational impact.

One of the key findings is that hand-drawn animated cartoons, by leveraging visual storytelling, can effectively bridge the gap between abstract control theory and real-world applications. This approach enables students to develop intuitive mental models by linking technical concepts with everyday scenarios. For example, using relatable narratives not only simplifies the presentation of topics such as PID control or Model Predictive Control but also fosters deeper engagement by appealing to both cognitive and emotional aspects of learning.

Furthermore, the project has demonstrated that the integration of artistic elements – such as carefully designed characters, expressive animations, and dynamic voiceovers – enhances the retention of complex ideas. These creative choices support the dual coding theory, where information presented both visually and verbally strengthens memory formation. In this way, the ∞sCaR project aligns with contemporary pedagogical theories that advocate for multimedia learning environments to reduce cognitive load and promote active learning.

The iterative development process, which has involved continuous feedback from educators, students, and industry experts, ensures that the content remains both technically rigorous and pedagogically effective. Future work will focus on incorporating interactive features, such as in-video quizzes and simulation modules, to further reinforce learning outcomes and provide immediate feedback to the viewer.

Finally, by adopting a design strategy that prioritizes accessibility and inclusivity – through neutral, universally appealing characters and online content with adjustable playback and subtitles – the project supports the goal of reaching a diverse audience. This is particularly important for encouraging underrepresented groups in Science, Technology, Engineering, and mathematics (STEM) fields to explore careers in Control Engineering.

6. CONCLUSION

This paper proposed and discussed the development of some video cartoons to communicate and disseminate the basics of Control and feedback systems. According to the early experience on this project, the authors strongly believe that the use of cartoons can contribute to simplify abstract theories through visual storytelling, making it easier for students to grasp difficult topics. Cartoons can also improve retention and recall by presenting information in a memorable and entertaining way. Furthermore, they encourage creativity and critical thinking by illustrating real-world engineering challenges in a fun and relatable manner. By reducing cognitive load and increasing student motivation, cartoons foster an interactive learning environment that enhances comprehension and problem-solving skills.

As the ∞sCaR project progresses, an important aspect to be addressed is the evaluation of its effectiveness in enhancing Control Education. While the development of the animated videos is ongoing, future efforts will focus on assessing their educational impact and refining their design based on audience feedback.

Several key objectives have been identified for the next phases of the project:

- *Engagement and motivation:* A structured evaluation framework will be designed to measure how animated videos influence students' interest in Control Engineering, particularly among those encountering the subject for the first time.
- *Concept comprehension:* The effectiveness of the videos in conveying fundamental Control concepts, such as feedback and stability, will be analyzed through structured assessments and qualitative observations.
- *Inclusive learning:* Particular attention will be given to the role of artistic elements in making Control concepts more accessible, especially for underrepresented groups in STEM fields.

To achieve these goals, planned activities include pilot studies in university courses, collection of structured feedback from students and educators, and iterative refinements of the video content.

A taxonomy-based quantitative analysis of the developed animated cartoons and associate quizzes will be done in a similar way as in (Knorn et al., 2024a). Analyzing the combination of Art and Science through animated Control cartoons to increase the students' engagement is ongoing work (Stoica et al., 2025). The ∞sCaR project also aims to explore ways to integrate these resources into broader educational initiatives, ensuring their long-term impact and accessibility.

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