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# An autonomous low-cost studio to record production-ready instructional videos

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**Abstract**
Producing high-quality educational videos usually requires a large budget as it involves the use of expensive recording studios, the presence of a technician during the entire recording session and often post-production tasks. The high costs associated with video production represent a major hindrance for many educational institutions and, thus, many teachers regard high-quality video recording as inaccessible. As a remedy to this situation, this article presents SAGA (Autonomous Advanced Recording Studio in its Spanish acronym), a low-cost autonomous recording set that allows teachers to produce educational content in video format in an agile way and without the need for post-production. The article provides an overview of SAGA, including a description of its hardware and software so that anyone with basic technical knowledge can replicate and operate the system. SAGA has been used to record more than 1,500 videos including the contents of six MOOCs hosted on the MiriadaX platform, as well as four courses at UPM. SAGA has been evaluated in two ways: (1) from the video producers' perspective, it was evaluated with a questionnaire based on the Technology Acceptance Model, and (2) from the video consumers' perspective, a questionnaire was conducted among MOOC participants to assess the perceived technical quality of the videos recorded with SAGA. The results show a very positive general opinion of the SAGA system, the recorded videos and the technical features thereof. Thus, SAGA represents a good opportunity for all those educational institutions and teachers interested in producing high-quality educational videos at a low cost.

**Keywords** Recording studio · Instructional videos · Video equipment · Multimedia materials · Technology acceptance model

## 1 Introduction

Instructional videos are those that have the objective to help someone learn about specific concepts or procedures [1]. Although they have been widely studied in different dimensions, e.g., learning effectiveness, teaching methods, design, and reflection [2], they continue to arouse an important interest among researchers and education

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professionals, especially with the rise of online learning in the form of Massive Open Online Courses (MOOCs) and other distance learning environments, as well as the situation caused by the COVID-19 pandemic. It is generally accepted that instructional videos, when produced and used correctly, can serve as a powerful and effective teaching tool [3, 4] improving learning outcomes as well as learner satisfaction [2].

Using recorded videos in face-to-face learning as a complementary tool is a practice that has proven effective to bring multiple possibilities [5], such as free class time for learner-centred activities [6], or directly flip the classroom [7]. In general, the provision of lecture capture recordings is perceived by students as helpful for learning and as strongly enhancing their learning experience [8, 9]. However, whereas video is important in face-to-face learning, its role in online distance learning has become crucial, being the main vehicle of content delivery in nearly all MOOCs and other types of online courses [10].

Creating high-quality videos is not a trivial task that any teacher can deal with. For the complimentary videos used to support face-to-face learning, teachers usually resort to screen capture technologies [11–13] or videos directly recorded with mobile phones [14, 15]. However, in the case of online courses, especially MOOCs, it has been demonstrated that the more satisfied a student is with the teaching material the more probable it is that he/she will successfully complete a course [16, 17]. Moreover, there is a trend for institutions toward opting for a professional, studio-style setup when producing videos for MOOCs [10]. There is also a consensus that video production, in nearly all cases, is the most expensive component of creating a MOOC [10]. In this regard, Hollands and Tirthali [18] found the quality of videography to be one of the major cost drivers of MOOCs. Based on U.S. national average prices, they estimated the cost of one hour of high-quality, finished video to be $4,300, which makes it unaffordable for many institutions and educators interested in offering these kinds of courses. In an attempt to make video production easier with some level of standardization at the institutional level, some educational institutions have made available one or two professional recording studios at their headquarters or main offices that can be booked by teachers in time slots. On the one hand, this can pose a bottleneck as there are only one or two studios to serve the full teaching staff of an institution. On the other hand, it implies a high cost, as setting up these studios can be extremely expensive; they may require support from a technician during the recording sessions, and sometimes post-production tasks are needed as well. Indeed, staff time was cited as the most costly piece of this process [10].

Although there is no standardized taxonomy of educational video styles for MOOCs, Santos-Espino et al. [19] studied 115 MOOCs from different institutions, on different subjects and delivered via different platforms to group the videos in styles and determine which styles are most commonly used. The resulting classification consisted of seven main styles:

- Talking head: Human speaker who covers a large frame area (+30%) and is not surrounded by slides or other text-rich elements.
- Live lecture: Live recording of a classroom lecture or conference talk.
- Interview: One person or more answer questions or discuss a topic.
- Screencast: The visual recording of a computer session screen output. It usually includes a voice narration with a description of the actions being taken.
- Virtual whiteboard: A virtual whiteboard is shown where an instructor draws content (e.g., mathematical formulas, diagrams, or short text).

- Slides: An animated sequence of Powerpoint-like slides with a voiceover talk. Most frequent versions of this style display the speaker as a small "talking head" placed in a marginal area of the frame.
- Documentary: The standard cinematographic genre whose typical structure consists of narration and filmed segments of stock material about a topic.

In the same study [19], the authors concluded that, in general, the studied MOOCs combine two video styles, and that "talking head" and "slides" were the most widely used styles, present in 63% and 57% of the studied MOOCs respectively. This finding may come as no surprise since Guo et al. [20] measured the engagement of different video types and concluded that the "talking head" style is the most engaging one, and that videos that intersperse an instructor's talking head with slides are more engaging than slides alone. This finding is consistent with those of Kizilcec et al. [21], who stated that whereas no significant difference in short- and medium-term recall ability was found, including the speaker image in video instruction is encouraged based on learners' positive affective response since they strongly preferred instruction with the face and perceived it as more educational.

In summary, although instructional video recording is a necessity in most institutions to produce MOOCs and other types of courses, and even though this necessity has been further strengthened due to the situation caused by the COVID-19 pandemic, institutions lack a cost-effective way to offer their instructors the possibility to generate those contents. This article aims to fill this gap by describing SAGA (Autonomous Advanced Recording Studio, in its Spanish acronym), an autonomous recording studio that can be used to produce high-quality instructional videos for MOOCs and other educational purposes. The total cost of the studio is around 3,000 € and it does not require the presence of a technician in order to record videos or for post-production. Thus, the system is affordable for most institutions and opens new possibilities for instructors to create high-quality videos.

This system was created at the Department of Telematics Engineering of Universidad Politécnica de Madrid (UPM) in 2013, in the context of an educational innovation project called "ComunicaMedia" funded by the same institution. The development of SAGA was possible thanks to the advances in hardware and software that reduced the costs of computers and multimedia equipment while increasing their capabilities. Since 2013, the system has evolved as the hardware and software improved, and also by introducing new features and improvements extracted from the feedback received from the users. To date, SAGA has been used to record more than 1,500 videos, it has been used to record the contents of the different editions of six MOOCs offered at the MiriadaX platform [22], with more than 300,000 students enrolled overall and also all the contents of four on-campus courses at UPM. Furthermore, in 2019, considering the potential that SAGA had, UPM decided to install 18 more of these systems in other UPM schools to allow more teachers to record their own videos. The system was evaluated in 2021 in two ways: (1) from the video producer's perspective, through a questionnaire based on the Technology Acceptance Model, and (2) from the video consumer's perspective, through a questionnaire about the perceived technical quality of the videos. The evaluation results show that instructors had a very positive overall opinion of the system and will use it again in the future and MOOC participants rated the technical characteristics of the videos very highly.

The rest of the paper is organized as follows: Section 2 presents the current state of the art on instructional video production. Section 3 describes SAGA in detail so that anyone with basic knowledge of hardware and software can replicate the system. Section 4 presents the results of the evaluation conducted. Lastly, Section 5 draws some finishing conclusions and provides an outlook on the limitations of the system and future work.

## 2 Related work

When resorting to recording instructional videos, one of the first options available to teachers is recording lectures. Lecture capture systems constitute a wide area of research. Many systems that perform efficient lecture recording can be found in the literature [5], including portable systems [23], automated systems [24, 25] and cost-effective systems [26]. One very extended solution —as it is open source and supports not only the capture of a lecture but also its distribution— is Opencast (formerly known as Opencast Matterhorn) [27, 28]. Many studies have demonstrated the usefulness of lecture recordings in many learning scenarios. Soong et al. [29] found that 94.9% of a total of 1,140 surveyed students agreed or strongly agreed that the video recorded lectures were useful in relation to their studies in the university. Nevertheless, it has been also found that high-quality pre-recorded classroom lectures are not as engaging when reused for a MOOC [20].

Recording studios play an important role when producing video, especially for MOOCs and other online courses [10]. Research on recording studios has led to impressive systems such as the one described by Theobalt et al. [30], who presented a recording setup for multi-view video acquisition that enables the synchronized recording of dynamic scenes from multiple camera positions under controlled conditions, and Ma et al. [31], who reported on a multimedia authoring system that constructs and presents multimedia content to students for either offline or online usage supporting multiple connection rates. Other systems reported in the literature [32–35] are focused on the improvement of professional studios by adding different features, e.g., virtual reality, augmented reality and the possibility of interaction with virtual objects. Although these systems are suitable solutions to the problem that they attempt to solve and add interesting functionalities to recording studios, they are not affordable for tight budgets. Even a simple recording studio, without any additional enhancements, is beyond the budget of many institutions, especially when multiple instances are required to serve a large teaching staff. The cost of facilities, equipment and support staff can exceed 150,000 € [36].

In this regard, some recording studios have been reported in the literature that target more modest budgets. One of them is Polimedia [37, 38], a system based on Opencast and developed by Universidad Politécnica de Valencia (UPV) which deploys a camera, two PCs, a pocket microphone, lights and some A/V equipment, including a video mixer, and an audio noise gate. It has been thoroughly used at UPV to create MOOC videos and video learning objects [39]. It costs around 30,000 € per deployment, and it still needs the presence of a technician during the recording sessions. The only video recording, to the knowledge of the authors, that can be used by teachers alone without the need for a technician is One Button Studio [40]. This system was created by Pennsylvania State University in 2015 and made public in 2017 [41]. Since then, it has been installed in multiple libraries at different American universities. Its cost is around 9,000 € per installation and it is completely automated. Users only need two flash drives: one to store the resulting recording and an extra one if they would like to include a PowerPoint presentation within their video. According to the official documentation, it enables users to produce professional-quality presentations and green screen recordings by simply pressing a single button. It is only compatible with macOS as it is based on hardware and applications that only run on said operating system family. This dependency is one of its major drawbacks as with the macOS update to macOS Mojave 10.14 in September 2018, Pennsylvania State University announced that they could not fully test all the hardware and software pieces in the newest operating systems leaving the new installations on their own. The One Button Studio

official application that runs the whole studio is available for free at the Apple Store but its source code is private, so it cannot be modified or improved by the educational community. McCorkle (one of the authors of One Button Studio) and Stryker have recently proposed an alternative solution called One Button Video Kiosk [42] inspired by the original design of One Button Studio but with a special focus on affordability, using consumer-grade equipment. They do not specify the detailed cost since they reuse equipment, but it is around 2.500 €. This system is designed for web-quality video production, as they have reduced the cost so much that the system uses a webcam with a built-in microphone for video and audio. Also, the system has not yet been evaluated. Finally, another video production studio that uses green screen and is affordable has been recently published by Chan [43], but it is not intended to record videos but to stream them in online sessions using Zoom videoconference technology.

In view of the previous facts and considerations, educational institutions are not able to offer their teachers a simple and inexpensive way to record instructional videos, ultimately resorting to professional, studio-style setups [10] that are highly costly. A well-documented and updated system that multimedia departments of the educational institutions could assemble themselves is a necessity, and it would pose a great contribution to the sustainability of the educational system and the fulfilment of the Sustainable Development Goal number 4 "Quality Education" [44].

## 3 SAGA: Autonomous Advanced Recording Studio

This section presents SAGA, an autonomous low-cost recording studio to produce high-quality instructional videos. SAGA offers a high level of flexibility in terms of video styles that can be recorded. The user can choose whether to appear on the recording and if so, whether to sit or stand. Furthermore, thanks to the use of a chroma-key (green screen) the background can be replaced by an image, a slideshow, or the device (computer or tablet PC) screen directly connected to the system. Following the classification outlined in the introduction these video styles would be called "talking head", "slides" and "screencast" (these two last ones can be combined with the appearance or not of the speaker). Furthermore, SAGA allows the combination of these video styles into one video, changing the style in the middle of the video, for example, from talking head to slides alone or slides with the lecturer. Screen captures of four different videos recorded using SAGA can be seen in Fig. 1.

The system has extensive documentation and an online course where the users can learn the basic concepts of its operation before using it for the first time. On the first day, it is recommended that the user is accompanied by a technician that may solve any doubt, help connect the user's computer or tablet PC and show how to start the full system. However, this is not necessary, as SAGA is completely autonomous since it can be operated by the user on its own without the presence of a technician. This autonomy is the main cost-cutting aspect of SAGA since, as pointed out by Hansch et al. [10], staff time was identified as the most costly piece of the video recording process.

SAGA does not require post-production. The resulting product is a high-quality H.264 video ready to be distributed. Moreover, fade-in and fade-out transitions (sometimes called jingle or bumpers) can be added automatically by SAGA if wanted. The next subsections describe the hardware and software parts that compose the SAGA studio.

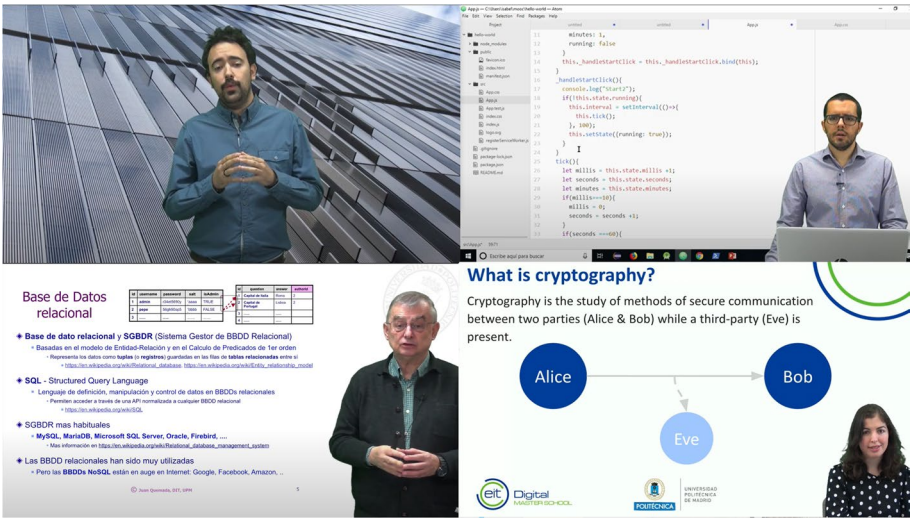


**Fig. 1** Four videos recorded with SAGA

### 3.1 SAGA hardware

The creation of SAGA was possible thanks to the big advances in hardware that reduced the costs of computers and multimedia equipment while increasing their capabilities, especially the computing power and the graphic cards that have evolved substantially in the last decades and are needed for real-time keying (i.e., removing the green screen background) to avoid post-processing. Figure 2 shows the hardware diagram of a SAGA typical installation.

The core of the system is the recorder PC, which is a computer with at least 8GM RAM, 3.5 GHz, and SSD storage of 256 GB. This computer is additionally equipped with an HDMI capturer to connect the HD camera video output and a DVI capturer with multiple adapters (HDMI, VGA, DisplayPort, Mini DisplayPort, etc.) to connect the user PC or tablet output. The recorder PC has a duplicated monitor, keyboard and mouse kit: one set for the user to control the recorder PC and another one for an occasional technician. The cost of the recorder PC with the two capturers is around 1,500 € (including a Windows 10 operating system license); the monitor costs around 100 €, keyboard and mouse kits can be found for around 20 €, and the HD camera and tripod cost around 700 €. Exact pricing of the hardware components can be found on Table 1.

The audio is captured with a lavalier lapel microphone that provides high-quality audio while at the same time being wireless and small. It allows the user to freely move and is barely noticeable in the final recording. The cost of this kind of microphone is around 200 €.

The room in which the system is set up is furnished with a chroma key (green screen) for real-time keying and a set of LED lights to avoid unwanted shadows in the face and body of the user. This set of lights is a component that has also decreased its price noticeably in the last few years and, thanks to the LED technology, it is light and very powerful. The cost of the chroma key and a lighting set is around 150 €.

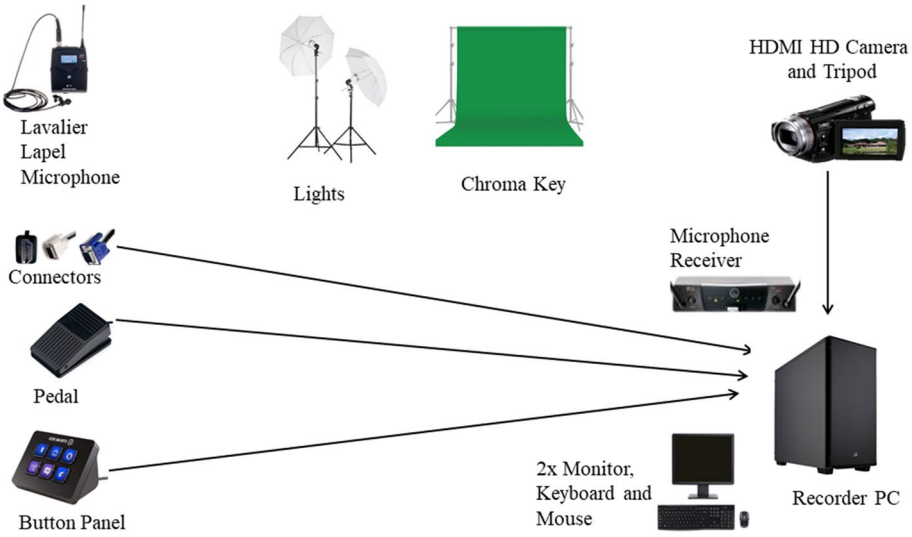


**Fig. 2** SAGA hardware diagram

**Table 1** SAGA Hardware components and pricing

| Hardware component | Price in € |
|---|---|
| Recorder PC (HP ProDesk 400 G6—core i7 9700, 16GB DDR4 RAM, 512GB SSD) | 872 |
| DVI Capturer (Magewell Pro Capture AIO) | 435 |
| HDMI Capturer (Blackmagic Design DeckLink Mini Recorder) | 131 |
| 2×Monitor (Sceptre 24" E248W LED Monitor 1080p) | 254 |
| 2×Keyboard & Mouse (Verbatim Slimline) | 25 |
| Tripod (Tripod Hama Star 64) | 49 |
| HD Camera (Sony FDR-AX43 4K Camcorder, Exmor R CMOS Sensor, Vario Sonnar T* Zeiss Optics with 20×Optical Zoom, B.O.SS. Image Stabilisation) | 647 |
| Lighting kit LED and chroma key (MOUNTDOG Photography Lighting Kit, 6.6X10ft Backdrop Stand System and 900W 6400K LED Bulbs Softbox and Umbrellas Continuous Lighting Kit) | 143 |
| Lavalier lapel microphone (AKG Pro Audio Perception Wireless Microphone System with SR45 Stationary Receiver, PT45 Pocket Transmitter, and CK99 Lavalier Microphone) | 199 |
| Pedal (PCsensor USB Foot Switch) | 16 |
| Button panel (Elgato Stream Deck Mini—6 button panel) | 66 |
| Cables and connectors | 110 |
| TOTAL | 2,947 |

Two essential components that enable the autonomous recording and the achievement of a professional result are the button panel and the pedal. The button panel consists of a small deck with 6 LCD buttons, in which each button can be customized with a different image and feature of the system. For example, these buttons can be used to start or stop the recording, switch video style, or any common function that the user wants to have direct and quick access to. Its cost is around 100 €. In SAGA, the pedal is used to stop the

recording when standing without having to use the button panel or the mouse to click an icon on the PC interface, which would force some post-production to cut the final seconds of the video. The cost of the pedal is around 30 €. The full setup of the SAGA room can be seen in Fig. 3.

SAGA uses commodity hardware that can be bought at affordable prices at any computer store. Table 1 shows a summary of the hardware, detailing for each component a specific candidate in parentheses, and prices as of February 25th, 2022, at the amazon.com store.

Since the inception of the system in 2013, different hardware configurations have been tested to try to minimize the cost while maintaining the compromise of usability and resulting video quality. One attempt was replacing the recording PC with an Ubuntu-based computer to avoid the Windows license cost, but the user experience was worse according to the feedback received. Another attempt was to replace the camera for a cheaper one but the final quality worsened.

### 3.2 SAGA software

The latest advances in video capture software were also a cornerstone in the development of SAGA, especially OBS Studio [45] and its broad community. OBS Studio is a piece of open-source software designed for capturing, compositing, encoding, recording, and streaming video content efficiently. OBS Studio, being a very powerful and versatile tool, has been successfully used for different purposes such as creating video lectures [46] and broadcasting game plays [47]. It is a complex piece of software with many options and possibilities. The two main features of the software that make a difference in our use case are *Sources* and *Scenes*. OBS supports a wide variety of *Sources* to be integrated into a *Scene*. The main *Sources* are media (audio, video, image), an external capturer, and the computer


**Fig. 3** SAGA room setup

screen (the whole screen or a specific application). *Sources* are used to compose what is called a *Scene* in OBS, i.e., a group of *Sources* with their positions and sizes forming a specific layout.

Another important aspect of OBS that should be noted is that it incorporates hotkeys functionality. The pedal, when pressed, sends a customizable key command to the computer. This key must be mapped in OBS to stop the recording. The same happens with the six-key button panel, which can be customized to perform specific actions in OBS that can be set up when installing the system. It is recommendable to enable three keys for specific video styles: one key to stop the recording (in case the user does not want to use the pedal when sitting), and the two remaining keys for additional functions such as entering and exiting full screen mode when recording or enabling/disabling a timer to know the time spent recording.

Additionally, OBS supports a variety of plugins to extend its functionality. SAGA uses a single plugin called Advance Scene Switcher to switch *Scenes* using transitions and to programmatically start and stop the recording, which allows to start the recording with a video bumper or jingle or to stop the recording after it ends.

The other software that SAGA studio uses was specifically developed by UPM to automate different common processes and actions, as well as to facilitate the use of the SAGA system. This ad hoc program was directly called SAGA app and it was released as open-source software under a GNU Lesser General Public License v2.1 [48]. In the next paragraphs we describe the most recent version of this application, but we have to thank all the feedback received since the inception of SAGA that allowed us to fine-tune the system. In the first version of SAGA in 2013 there was not even a SAGA app, and OBS studio was directly used to record the videos. This software presented many options and users found it difficult to get it working.

The user interface of the SAGA app can be seen in Fig. 4. The central part of this app shows a dropdown menu where the user can select the appropriate *Scene* (referred to as video styles in the first section of this article). The two buttons on the sides of the dropdown allow creating a new *Scene* by copying the selected one and removing it. The app also offers a search box to facilitate the *Scene* selection in case there are many of them available and they are difficult to browse. Below the *Scene* selector, the largest buttons allow the user to perform the three most common actions: “preview” the selected *Scene* to see how the final layout will be and get into place (standing or sitting); “record”, that will start the recording with the selected *Scene* layout with a specified delay so the user has enough time to get into place; and “browse my videos”, which opens the videos folder containing the previously recorded videos, enabling the user to copy them to a USB flash drive or to share them in some other way.

SAGA app also integrates some additional utilities and tools situated at the bottom of the app interface. The first one is a feature to combine multiple videos into one in case the user records multiple video chunks and wants to easily join them. This feature also warns users if it detects silences longer than several seconds (customizable) in the videos, as well as in case the microphone ran out of battery and the user did not notice it when recording. Moreover, the SAGA app has a “Devices” button that offers some functions to test the hardware (camera, microphone, pedal…) individually and check that everything is working properly in the system. This function also makes it possible to monitor the microphone in case it fails, runs out of battery or the volume is below a threshold, displaying a warning dialogue in those cases. The third button enables a teleprompter functionality, whose content, speed and position can be customized. Finally, some buttons to access documentation and frequently solved problems or get help are also provided.

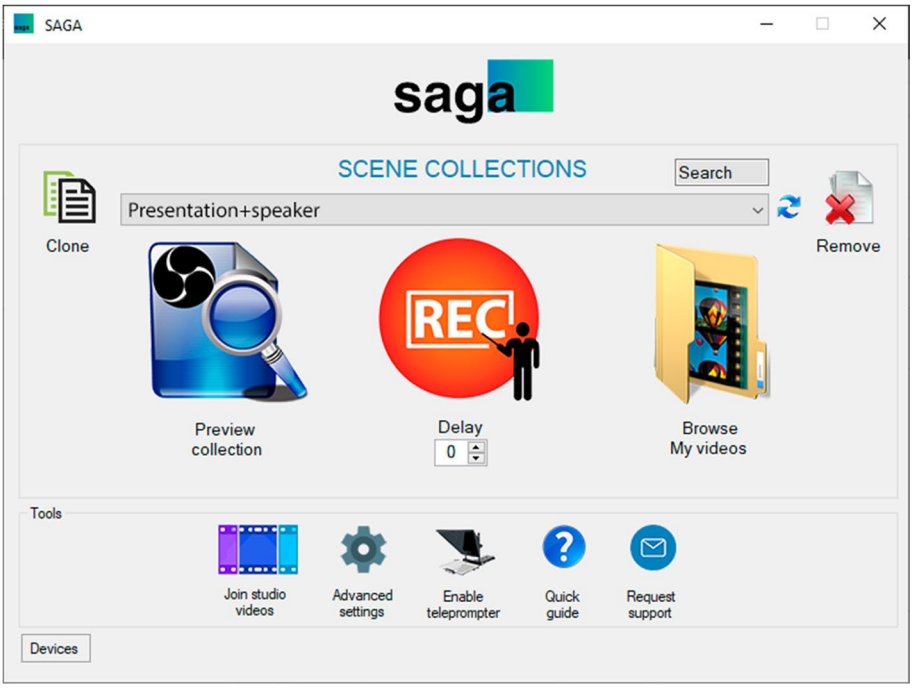


**Fig. 4** Screenshot of the SAGA app

### 3.3 SAGA user guidelines

Due to the autonomous nature of SAGA, the user is expected to be alone in the room and should take into account several recommendations to be able to make the most of it.

In the first place, users should be at least two feet away from the green screen (preferably three feet). This helps minimize spill (the reflection of the light from the green screen) and unwanted shadows appearing on the green screen background.

As for the lavalier lapel microphone, one important aspect to consider is that it should not touch the speaker's clothes because it would introduce noise. Thus, it is crucial to clip it properly. Additionally, the distance between the microphone and the mouth should be around 25 cm. This distance may vary depending on the hardware sensitivity and, hence, it should be tested in advance before the first recording.

In most of the SAGA assemblies, two additional components were included, headphones, and a wireless presentation remote. The headphones for the user to listen to the resulting video and better check the audio quality and possible noises and the presentation remote in case the user needs to change slides and forgets to bring one.

### 3.4 SAGA system uses

The SAGA system has been used to record the totality of the videos of six different MOOCs offered at the MiriadaX platform, which have been very successful, with several editions offered for each of them and more than 300,000 enrolments altogether.

The system has been also used to record all the contents of four on-campus courses of the bachelor's degree in Telecommunications Engineering from UPM. One course was completely recorded in 2018 to be able to use the flipped-classroom methodology. Three additional ones were recorded in 2020 due to the COVID-19 pandemic and the switch from face-to-face to a fully online teaching methodology.

All the videos of these six MOOCs and two of the four on-campus courses were uploaded to a YouTube channel [49] that, at the time of writing, had 687 videos, 14,500 subscribers, more than 4.3 million visualizations, and 386,000 viewing hours.

Due to the ease of use of the system, the possibilities that it offers, and the tight budget required to assemble it, the SAGA system has been recently installed in 18 schools of UPM, being accessible to all the teaching and research staff of this institution, composed of more than 2,500 people.

## 4 Evaluation, results and discussion

### 4.1 Evaluation

SAGA is a recording studio designed to produce instructional videos. It has been described in detail in the previous section as it comprises hardware and software that should be assembled and installed. Two agents are involved in the use of this system, the producer of the videos and the consumer, i.e., the instructors that record the videos and the students that use them to learn. Thus, SAGA was evaluated from those two points of view. From the video producer's perspective, SAGA was evaluated with a questionnaire based on TAM and, from the video consumer´s perspective, another questionnaire was conducted among the MOOC participants of the 2020–2021 edition of the MOOCs to assess the perceived technical quality of the resulting videos.

TAM was chosen because it is considered the most influential and commonly employed theoretical framework for describing an individual's acceptance of information technology [50]. It is a powerful vehicle to describe teachers' technology adoption [51]. TAM was initially proposed by Fred D. Davis [52] and comprises several variables explaining behavioral intentions and the use of technology directly or indirectly, i.e., perceived usefulness, perceived ease of use, and attitudes toward technology. A questionnaire based on TAM and adapted to the context of this study was designed. The questionnaire items include perceived usefulness, perceived ease of use, attitude toward using, and intention to use. Questionnaire items were measured using a 5-point Likert scale ranging from "strongly disagree" to "strongly agree". The questionnaire was distributed online to teachers that have used SAGA during the year 2021. A total of 31 teachers answered the questionnaire, 64.5% (20) males and 35.5% (11) females, ages ranging from 27 to 68 ($M = 47.9$, $SD = 10.5$). Research on TAM has identified two primary constructs that predict technology acceptance: perceived usefulness and perceived ease of use [52]. We calculated the correlation of all pairs of items of the questionnaire to test the relationship among all the constructs proposed in TAM.

A questionnaire about the perceived technical quality of the videos was conducted among the participants of the 2020–2021 edition of the different MOOCs in which the SAGA system was used to record all the videos. The questionnaire consisted of some questions to collect demographic data (age and sex), five questions where respondents had to

rate, using a scale of 1 (poor) to 5 (excellent), the quality of a set of characteristics of the videos, four Likert-type questions with five answer options (1 Strongly disagree—5 Strongly agree) and finally an open question asking participants to provide comments and suggestions for improvement. A total of 703 students answered the questionnaire, 79.8% (561) males, 18.9% (133) females, and 1.2% (9) chose not to indicate their gender. Respondents were between 18 and 77 years of age (M = 47.6, SD = 11.1).

### 4.2 Video producers results and discussion

The results of the questionnaire conducted among instructors who have used SAGA is shown in Table 2. Questions are divided into the four constructs that the TAM model proposes: perceived usefulness, perceived ease of use, attitude toward using, and intention to use. The internal consistency of each of the constructs was checked through Cronbach's alpha [53], resulting in very high values for all the constructs (between 0.81 and 0.92). Regarding the first construct, *perceived usefulness*, the three questions were rated with a mean (M) ranging between 3.9 and 4.2, indicating that instructors' perception of the utility and usefulness of the system is good overall, i.e., that SAGA is useful for its intended purpose of recording educational videos. The second construct, *perceived ease of use*, was the one with the lowest opinions, with a mean ranging between 3.6 and 4.3 out of 5. These results indicate that SAGA is easy to use although there is room for improvement. In fact, 19% (6) respondents disagreed with statement E3, i.e., did not find it easy to get SAGA to do what they wanted it to, which may constitute an adoption barrier. SAGA has multiple hardware components that must be initiated when entering the room and the user interface has multiple options making it somewhat confusing for some users. With the aim of improving these results in future uses and evaluations of the system, additional documentation and video tutorials have been created. An online course has been produced and offered to all the teaching staff of the university. The course describes the system, its operation, possibilities of use and solves frequently asked questions. Regarding the third construct, *attitude toward using*, there were two questions: the first one was about being productive when recording educational videos, which instructors mostly agreed with (M = 4.0) and the second one was about it being easy to become a good educational video maker using SAGA and instructors also agreed (M = 3.8). Finally, the fourth construct, *intention to* use, was the one with the highest agreement level, with a mean ranging between 4.3 and 4.4. Instructors agreed that using SAGA is a good idea (M = 4.3); that they will use it in the future if they have to record educational videos (M = 4.3), and they would recommend using it to their colleagues (M = 4.4). In the questionnaire, there was an additional question about the general opinion of the SAGA system, and overall, video producers had a positive opinion of SAGA (M = 4.2, SD = 0.8, MED = 4).

In addition to employing descriptive statistics to analyze instructors' responses, we studied the relationships among the different items of the questionnaire using correlation analysis (Table 3). First, the results show that items within the same construct were positively correlated to each other in a statistically significant way, corroborating the results obtained from the internal consistency measures (Cronbach's alpha). Most items related to *ease of use* were positively correlated with *perceived usefulness*, especially with item U1 which deals with the effectiveness of video recording, although lower regarding the ease of use of the SAGA interface (E5). *Attitude towards using* SAGA was highly correlated with *perceived usefulness* (especially between I1 and A1), and most items related to *perceived ease of use* (especially A1 and E2). Lastly, as the TAM model suggests, *attitudes towards using*

**Table 2** Results of the questionnaire conducted among instructors who used SAGA ($N = 31$)

| Construct | | Question | M | SD | MED | Cronbach's α |
|---|---|---|---|---|---|---|
| Perceived Usefulness | U1 | SAGA helps me to be more effective when recording educational videos | 4.1 | 1.0 | 4 | 0.86 |
| | U2 | SAGA is useful for my teaching practice | 3.9 | 1.0 | 4 | |
| | U3 | SAGA can help me to improve my teaching practice | 4.2 | 0.9 | 4 | |
| Perceived Ease of Use | E1 | SAGA has a clear and understandable function | 4.3 | 1.0 | 5 | 0.92 |
| | E2 | SAGA makes it easy to record educational videos | 3.9 | 1.0 | 4 | |
| | E3 | I find it easy to get SAGA to do what I want it to do | 3.6 | 1.2 | 4 | |
| | E4 | SAGA hardware is easy to start up | 3.8 | 1.2 | 4 | |
| | E5 | SAGA user interface set is easy to use | 3.9 | 1.0 | 4 | |
| Attitude Toward Using | A1 | SAGA makes me more productive when recording educational videos | 4.0 | 1.2 | 4 | 0.81 |
| | A2 | I believe that using SAGA it will be easy for me to become a good educational video maker | 3.8 | 1.2 | 4 | |
| Intention to Use | I1 | Using SAGA is a good idea | 4.3 | 1.0 | 5 | 0.91 |
| | I2 | I will probably use SAGA again when I have to record an educational video | 4.3 | 1.2 | 5 | |
| | I3 | I would recommend the use of the SAGA system to other teachers | 4.4 | 0.9 | 5 | |

**Table 3** Correlation matrix for the instructors' responses

| | U1 | | U2 | | U3 | | E1 | | E2 | | E3 | | E4 | | E5 | | A1 | | A2 | | I1 | | I2 | | I3 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| U1 | — | | | | | | | | | | | | | | | | | | | | | | | | | |
| U2 | 0.680 | *** | — | | | | | | | | | | | | | | | | | | | | | | | |
| U3 | 0.626 | *** | 0.729 | *** | — | | | | | | | | | | | | | | | | | | | | | |
| E1 | 0.694 | *** | 0.526 | ** | 0.457 | ** | — | | | | | | | | | | | | | | | | | | | |
| E2 | 0.822 | *** | 0.667 | *** | 0.473 | ** | 0.760 | *** | — | | | | | | | | | | | | | | | | | |
| E3 | 0.798 | *** | 0.606 | *** | 0.423 | * | 0.737 | *** | 0.886 | *** | — | | | | | | | | | | | | | | | |
| E4 | 0.717 | *** | 0.608 | *** | 0.533 | ** | 0.683 | *** | 0.696 | *** | 0.749 | *** | — | | | | | | | | | | | | | |
| E5 | 0.709 | *** | 0.360 | | 0.442 | * | 0.616 | *** | 0.675 | *** | 0.778 | *** | 0.743 | *** | — | | | | | | | | | | | |
| A1 | 0.856 | *** | 0.665 | *** | 0.503 | ** | 0.654 | *** | 0.812 | *** | 0.781 | *** | 0.622 | *** | 0.531 | ** | — | | | | | | | | | |
| A2 | 0.757 | *** | 0.610 | *** | 0.743 | *** | 0.488 | ** | 0.616 | *** | 0.521 | ** | 0.481 | ** | 0.510 | ** | 0.683 | *** | — | | | | | | | |
| I1 | 0.829 | *** | 0.615 | *** | 0.765 | *** | 0.545 | ** | 0.638 | *** | 0.572 | *** | 0.574 | *** | 0.540 | ** | 0.677 | *** | 0.841 | *** | — | | | | | |
| I2 | 0.686 | *** | 0.616 | *** | 0.687 | *** | 0.653 | *** | 0.607 | *** | 0.560 | ** | 0.422 | * | 0.325 | | 0.771 | *** | 0.763 | *** | 0.771 | *** | — | | | |
| I3 | 0.792 | *** | 0.664 | *** | 0.631 | *** | 0.743 | *** | 0.710 | *** | 0.659 | *** | 0.537 | ** | 0.415 | * | 0.848 | *** | 0.764 | *** | 0.744 | *** | 0.936 | *** | — | |

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

SAGA was highly correlated with respondents' *intention to use* the system. The obtained results reveal that, although *perceived ease of use* is related to *attitude toward using* and *intention to use*, the relationship of these with *perceive usefulness* is stronger, suggesting that users are willing to use SAGA for the purpose of recording their videos even if they find some difficulties. An issue to consider is that each respondent has used SAGA a different number of times and, therefore, early adopters might have stated that it was easier to use than newcomers.

At the end of the questionnaire, there was a space for comments and suggestions. Teachers mainly thanked for the possibility of autonomously recording videos without having to move to another location. Some teachers complained about the scene collection being misconfigured because a previous user had edited it. We have solved this issue in the present version of the SAGA app where provided scenes are read-only and the user can clone them and customize them with their name, keeping this way a personal scene that is maintained between recording sessions. There were also two suggestions to add a booking platform to the system, but that is out of the scope of the system due to each institution or school has its own booking system.

### 4.3 Video consumers results and discussion

The questionnaire conducted among MOOC participants was developed ad hoc for this research. The reliability of this questionnaire was evaluated by calculating Cronbach's alpha, obtaining a value of $\alpha = 0.89$, which indicates a good and acceptable internal consistency. The results are presented in Table 4. Respondents show they had a very positive overall opinion on the different technical characteristics of the videos evaluated: audio, image, synchronization, lighting, and framing. All of them were rated with a mean (M) ranging between 4.1 and 4.2 out of 5, a standard deviation (SD) between 0.8 and 0.9, and a median (MED) of 4. Respondents also strongly agreed that the fade-in and fade-out video bumpers were well-integrated (M = 4.0, SD = 0.9, MED = 4). These results clearly indicate that the perceived quality of the recorded videos is truly high.

Participants mostly agreed that MOOC videos were of sufficient technical quality to be able to learn with them (M = 4.2, SD = 0.9, MED = 4). They notably agreed that assuming a minimum technical quality, the content of the videos is more important than their technical quality (M = 3.7, SD = 1.1, MED = 4), and only slightly agreed that the technical quality of the video is a criterion that they usually take into account when choosing a MOOC (M = 3.5, SD = 1.2, MED = 4). These results confirm that videos recorded using the SAGA system can be effectively used as MOOC content. Additionally, although the content of the videos is more important than their technical quality, the latter can influence students' choice of one MOOC over another. This finding, together with the demonstration that the more satisfied a student is with the teaching material the more probable he/she is to successfully complete the course [16, 17], should raise the concern of educational institutions to enable their teaching staff with the possibility to record high-quality instructional videos in an easy and affordable way.

At the end of the questionnaire, students were asked to pose suggestions, comments, and/or complaints. Overall, most participants thanked the staff for taking the time and effort to create the videos. A couple of participants complained about the slightly different volume between the video bumpers and the lecturer's voice, another one about the high density of text in some slides that made them a little blurry on occasion, suggesting dividing them into two slides. Other two participants stated they would like to copy and paste

**Table 4** Results of the questionnaire conducted among MOOC participants ($N = 703$)

| Item | M | SD | MED |
|---|---|---|---|
| Please rate between 1 (poor) and 5 (excellent) the quality of the following characteristics of the videos: | | | |
| Sound/audio | 4.2 | 0.8 | 4 |
| Image (sharpness, contrast, …) | 4.2 | 0.8 | 4 |
| Audio/video synchronization | 4.2 | 0.8 | 4 |
| Lighting | 4.1 | 0.9 | 4 |
| Framing | 4.2 | 0.8 | 4 |
| Please, state your level of agreement with the following statements (1 Strongly disagree—5 Strongly agree): | | | |
| The fade-in and fade-out video bumpers are well integrated | 4.0 | 0.9 | 4 |
| The videos are of sufficient technical quality to be able to learn with them | 4.2 | 0.9 | 4 |
| For learning, I believe that from a minimum technical quality, the content of the videos is more important than their technical quality | 3.7 | 1.2 | 4 |
| The technical quality of the video is a criterion that I usually consider when choosing a MOOC | 3.5 | 1.2 | 4 |

content (especially source code) directly from the videos and be able to zoom on parts of the videos, which is out of the scope of the SAGA system and is more related to the distribution channel of the generated recordings.

SAGA has been evaluated from the producer and consumer points of view, obtaining very satisfactory results in both cases. Taking into account these results we can state that the SAGA system is valid to generate instructional videos with high technical quality, and due to its low-cost and extensive documentation, institutions will be able to install one or many SAGA systems in their facilities so they can be used by the teaching staff.

## 5 Conclusions

This article presents SAGA: an autonomous recording studio to produce high-quality instructional videos with a low budget. Both hardware and software of the system are described in detail so it can be replicated in other educational institutions.

SAGA has been used to record more than 1,500 videos, including all the contents of six MOOCs as well as four on-campus courses of the bachelor's degree in Telecommunications Engineering from UPM. An evaluation was conducted among video producers and among MOOC participants to see their opinion on the SAGA system and on the technical quality of the videos; this is, the image, audio, synchronization, lighting, and framing. On the one hand, video producers had a very positive opinion in terms of overall usefulness, ease of use, attitude toward using and intention to use the system. On the other hand, MOOC participants perceived the technical quality of the videos recorded with the SAGA system very high, making them adequate content for MOOCs. The participants also agreed that videos were of sufficient technical quality for them to be able to learn with them which is, in the end, the final goal of the courses. This is one of the aspects that differentiate SAGA from other systems, it has been widely used and evaluated from the point of view of video producers and consumers. The rest of the similar systems found in the literature have not been evaluated in this way or at all, being systems that are only an experiment to be used in a course.

From an economic point of view, SAGA, the system presented in this paper, poses a number of advantages. Firstly, it is low-cost —its price is around 3,000 €—, so almost any institution can afford to install one or several of these systems in their facilities, being much cheaper than other existing recording studios reported in the literature, such as Polimedia [37], with a price of around 30,000 € per deployment, or One Button Studio [41], with a price of around 9,000 €. Although there are more economical alternatives such as One Button Video Kiosk [42] (designed for web-quality video production) or the system proposed in [43] (used for videoconferencing), these are not as powerful and versatile and do not offer professional quality videos. Secondly, it is autonomous, not requiring the presence of a technician during the recording sessions. This causes the production of videos to be even cheaper compared with other systems that require such presence. Thirdly, the generated videos require no post-production, which is another aspect that could increase the final price-per-hour of videos. Lastly, it uses commodity hardware and open-source software (except for the Windows license) and it is not complex to assemble: with the information presented in this article and the available documentation of the system, a multimedia technician can install it at no additional cost. All these aspects make SAGA a remarkably affordable option when considering

the production of high-quality content for online courses and it can pose a great contribution to the sustainability of the educational system.

One limitation of SAGA is that it does not support camera control during the recording, as it is an autonomous system, and in order to move the camera or zoom in or out, there must be a technician present. Another limitation would be the need for adequate space, a quiet and unoccupied room to set up the studio.

An interesting future work would be to evaluate the ease of use and usefulness of the system depending on the digital competence of the instructors, to see if instructors with low digital skills get to use the system easily. Since the SAGA system can also be available for students (for example, to create assignments), it could be very interesting to analyse if they find any difficulty and if they experience an improvement in their communication skills due to the use of the system. Lastly, it would be very interesting to include in the system new cameras that promise background removal without the need for a green screen and examine the student's perceptions of the videos recorded with these new cameras.

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**Data availability** All data generated or analysed during this study are included in this published article and its supplementary information files.

The datasets generated during and/or analysed during the current study are available in the following OSF (Open Science Framework) repository: https://osf.io/5xkh9/

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.



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