

Repository of Open Educational Resources for Laboratory Support in Engineering and Natural Science-RELAB

Project Intellectual Output 3

Tutorial for the technical realization of “One- minute-experiment” video clips

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Introduction

“One-minute experiment” (abbrev. OMX) is video clip of limited duration, typically in 1-5 mins range, which depicts laboratory exercise, technical solution, interesting phenomenon, theoretical concepts e.g. physical laws, result or conclusion. In more general taxonomy of teaching materials, this can be considered as static object.

Having in mind pace of modern living, and ever decreasing span of attention of our students, this task can be rather challenging, requiring careful planning.

Intention of this tutorial is to provide guidance to small group or individual teachers, planning to create their own video materials, under assumption of low or moderate support by institution, either financial or assistance. Those institutions that have dedicated teams or resources for preparing video materials, are most likely already very familiar with this topic, so not the primary users of this tutorial.

As such OMX is meant to be important add-on in digital education, both as introductory material to certain lecture, topic, lab exercise and also as supporting clarification material. It can typically include mini-lecture and video-clip describing experiment. Primary idea is to provide students with major lecturing units to be explained quickly, underscoring and depicting most important items.

In addition, more routing or trivial, nevertheless important parts of lecturing, such as explanation how to use oscilloscope, voltmeter, assembly or lab setup, can be addressed in this way, and always available to students through open repository not necessarily completely public (not more than student login to e.g. Moodle).

Vido-clip should be complete, covering single topic, but it may also be part of mini-series of relevant series, hence including references or links to previous or future video-clips of same kind. Great attention should be paid to provided information, that respects ethical and scientific-educational norms – still it is recommended to insert intermittent less rigid/strict, comments or remarks to everyday life and examples that could steer additional student attention.

Why OMX and what topics to choose for OMX?

Video and multi-media can deliver much higher information bandwidth, than reading but there is MUCH more to that. Ultimate goal of teaching process is making students understand the topic, not just become aware of bunch of relevant facts. Also, increase productivity of learning, i.e. reduce student time coming to this goal (of understanding the topic, and enable him/her to autonomously expand the knowledge).

Even comparison between reading text on paper vs onscreen does not show straightforward answers. E.g. when reading texts of several hundred words or more, learning is generally more successful when it's on paper than on-screen. So, OMX-alone cannot be the major tool. But, it can be the valuable one, especially in increase of learning productivity.

We are all aware of modern era challenges for students like: diminished concentration, attention scope/duration, entertainment mindset, frequent multitasking while consuming digital content, lack of real world reference point, reduced reviewing of what's being already read/seen. Having said all this: OMX is digital content (and its pitfalls).

Modern communication platforms are overwhelmingly present. X generation students are just used to this way of communication, and content access. Habits and expectations from studies have changed significantly during last 20 years.

Having in mind relative easy of content creation, official educational institutions need to (continue) step(ping) forward and fill the void of "official" modern information dissemination materials. This will help keeping its relevance, but even more important, 'fight' uncontrolled dissemination of unofficial, quasi-teaching, not to mention quasi-scientific materials, undermining very foundation of scientific method as well as education of younger generation.

Having said that, it is necessary to ask ourselves what would be the differentiation, and not to be yet-another-video publisher, like many on popular platforms.

So, answer to what/why "official" OMX could be:

- Good method to abstract major punch lines in comprehensible way
- 'Warm-up' to teaching content, list questions, and real-life problems, certain teaching topic/course will try to address
- 'Warm-up', introduction to lab exercise
- Clarify using visual method certain tough to understand phenomenon
- Suitable methods on hand: live recording, screencast recording, animation, AR, infographics

In selection of right topic for OMX, we should have in mind: story layout, role of visualization, story progression and take-away/punch lines, i.e. what do we want exactly to achieve with certain OMX.

Long, complex lectures, requiring full mental focus are not good candidates, but OMX will indirectly help, saving time from more routine or more video suitable lectures, for difficult ones – saving time both for teachers and students.

OMX is natural ingredient of “Flipped Classroom” or “Flipped Lab” concept, where traditional ideas about classroom activities and homework are reversed, or “flipped.” In this model, instructors have students interact with new material for homework first. They then use class time to discuss the new information and put those ideas into practice.

E.g. for Lab exercise preparation, students can watch prep OMX video first, before coming to the lab, and thus save significant time reading scriptbook on lab site, understanding what to do... If OMX prep video is accompanied with the short-test, this becomes increasingly effective, since students that do not pass the test cannot come to the Lab and waste everyone’s time.

When it's time to film, keep it short and sweet. You'll be pleasantly surprised to learn that what used to take 15 minutes to cover in a lecture can usually fit into a 3-5minute video, since you won't have to worry about classroom management, and... don't be afraid to be entertaining!

OMX Examples:

- One-Minute Experiment, Example 1: The duration of the experiment is 2 [s], and OMX includes time response diagram as an Augmented Reality (AR) element on the short video

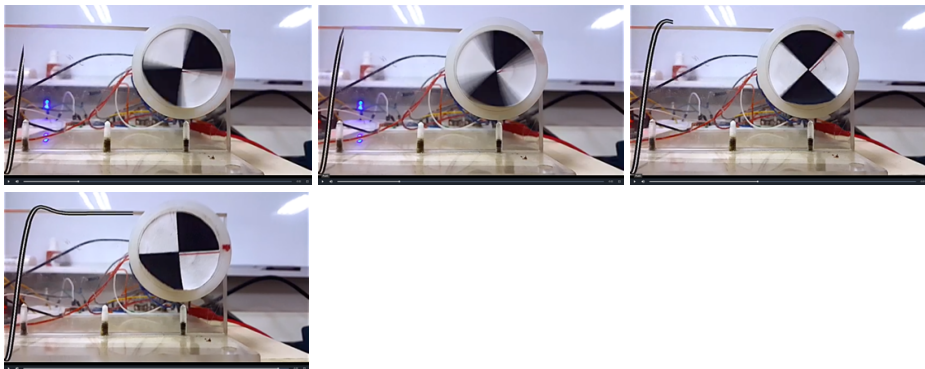
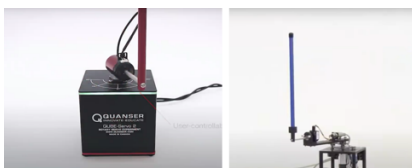


Fig. 1 DC motor shaft positioning: Aims of feedback control systems, Dynamical systems and transition processes, P regulator and servo motor.

- One-Minute Experiment, Example 2:

<https://www.quanser.com/products/rotary-inverted-pendulum/> (3 [s])



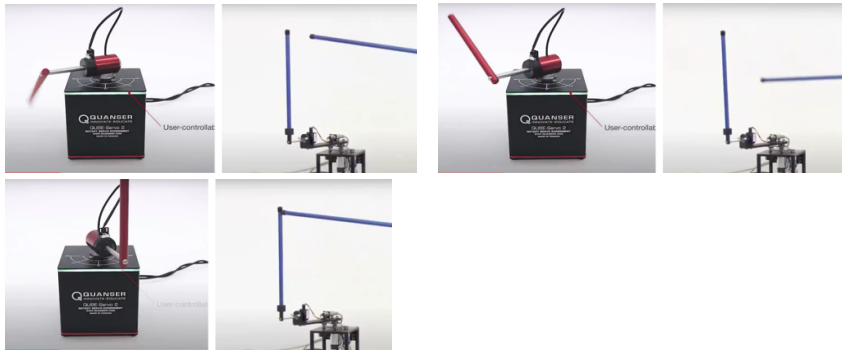


Fig. 2 Rotary inverted pendulum: control and disturbance signals, feedback control

- One-Minute Experiment, Example 3:

<https://twitter.com/valaafshar/status/1394827000519577600?s=21> (17 [s])



Fig. 3 Radiation experiments – the color white absorbs less light and less heat

- One-Minute Experiment, Example 4:

<https://twitter.com/valaafshar/status/1397960689352949764?s=21>

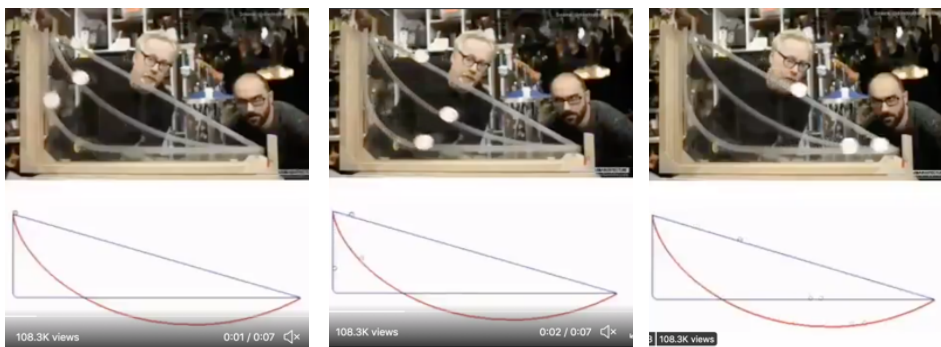


Fig. 4 Mechanical experiments - trajectory optimization

- One-Minute Experiment, Example 5:

https://s3-eu-west-1.amazonaws.com/klett-video/player/index.html?video=qr_vid_2021/qr36/stream

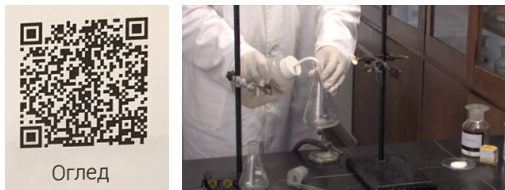


Fig. 5 Chemical experiments

To summarize, from educational point of view, the purpose of "One-minute experiments" would be:

- To help students to focus on the essence of the considered phenomenon,
- To help students to focus on just one term, concept, approach or phenomenon,
- To enable the availability and reproducibility of clear and representative short videos of explanations and illustrations of basic terms, phenomena, and important elementary parts of educational content,
- To reduce the level of abstraction of complex physical phenomena and theoretical concepts,
- To accelerate and increase the level of visualization, cognitive abilities and absorption of user knowledge,
- To be an option to replace demonstrative laboratory exercises - to help users of prepared content to correctly and quickly understand the teaching content (certainly faster than the textual description from the textbook or ex cathedra approach class),
- To provide new tools and supplements for existing conventional and blended learning methods,
- To support the process of digitalization of education as well as the concept of open education and open science,
- That the digital version of the demonstration laboratory exercises can be used in the most representative performance from anywhere, at any time, and with unlimited possible repetitions,
- That it can serve as an adequate replacement for demonstration laboratory exercises, especially in case of lack of real laboratory work (which is a real possibility in the COVID19 pandemic, but also a frequent occurrence in schools where there is a lack of human and material resources).

Classification

Short educational video materials describing lab experiments, can be classified into several major groups:

- Live recording
 - Created using physical setup, optionally including human presenter/demonstrator
- Screencast recordings
 - Recording of computer screen, either animated presentation or program showing lab setup readings, control/command/configuration
- Animated, or Virtual Reality
 - Virtual reality animation using appropriate software for rendering lab setup virtual description, perhaps movement of objects, reactions, readings etc.
- Augmented Reality, that is cross-breed between Live and VR recordings
 - This is special approach combining virtual objects and real-life recordings, but overlaid in such way that it becomes part of real-life scene, or overlaying text or marking, after identifying real-life object position and perspective – making scene immersive and better depicted.
- Mixed
 - This is going to be very frequently used method, with combination of few or all the above methods. It will allow best selection of method based on teacher's intention and requirements, in order to achieve best presentation results.

Initial Planning of Video Pre-production, Production and Post-production

Creating good, eye catching video material cannot be done in ad-hoc way. It requires careful planning, which can help reducing overall time spent. Method of trial-and-error is not good one, as it typically requires complete restart, rarely allowing reuse of any of the recorded/created material.

Following steps should be done, in this order:

1. Select appropriate topic, and goal
2. Create script
3. Decide about the format and type of video material (live, animated, screencast)
4. Create storyboard
5. Put a list of required shooting equipment and the setup. If something is not available, this is the right moment to estimate budget requirement, and get the approval at this point. Only at this point is elaborated enough, for you or your management to make a decision if it is worth progressing or not.

Next few steps are determined by video type

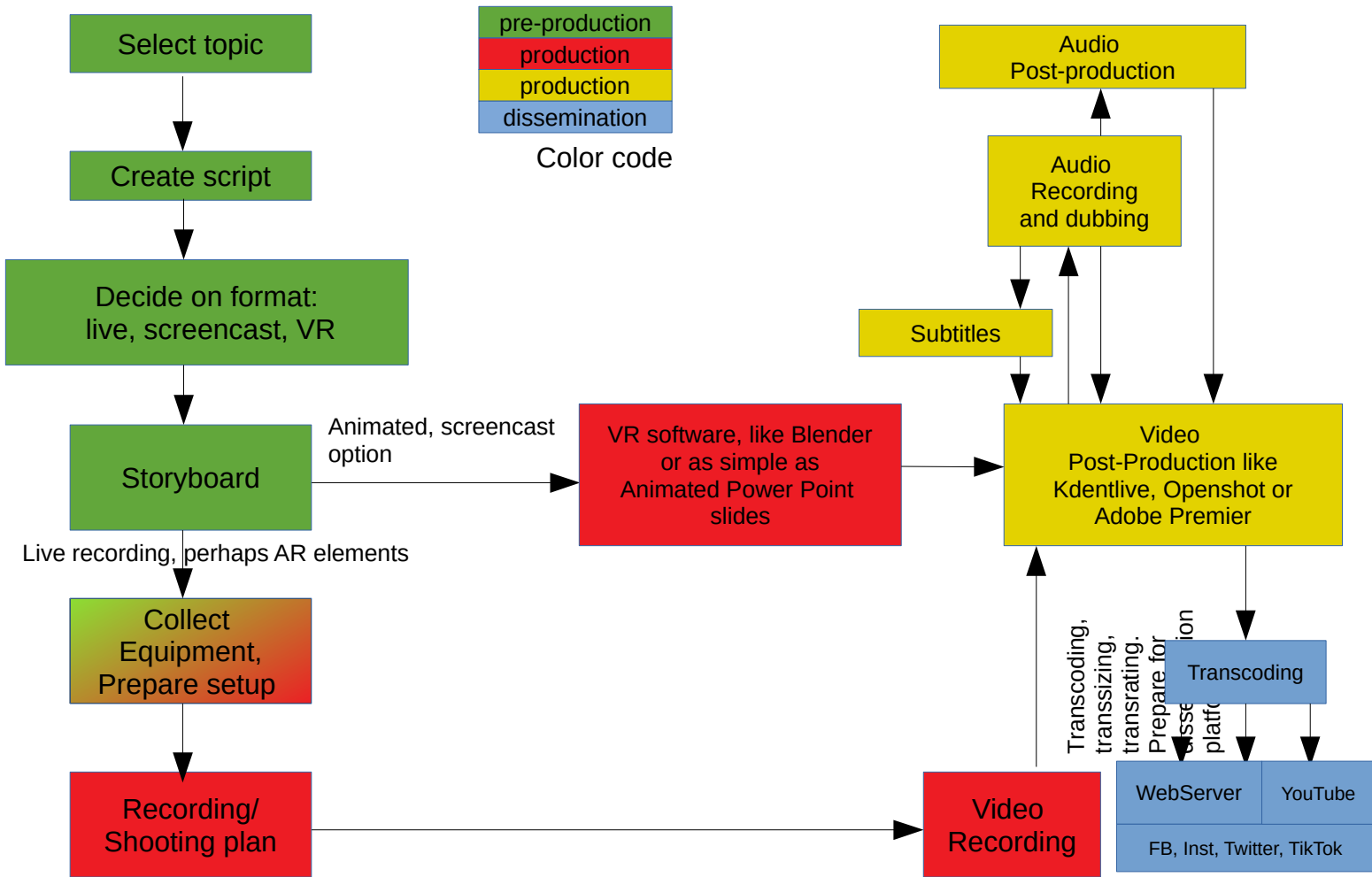
6. At the end, we always have video post-production to create candidate material
7. Finally, we should do audio recording and dubbing. At this point we may also need to deal with multi-lingual audio and subtitles.
8. Dissemination

Based on above required steps, we need to budget enough time for each step. Typically steps 2, 3 and 4 should not take more than 1-3 days, for video materials up to 2-3 minutes. Loosely speaking, this is video pre-production. These prep steps give you good information about required budget, and if necessary, at this point you have a complete plan, and may request approval or feedback from colleagues or managers

Step 5 can be time consuming and may take from couple of (1-2) days to couple (1-2) of weeks. This is video production.

Final steps, 6 and 7 are video post-production, and can consume as much time, or even more, than video production.

It is important to understand all the steps up-front, and based on resources avoid making too ambitious plans, as it may create unacceptable churn and the workload (making you to give up before task is completed).



Script

Script of video recording is a write-up to be prepared before any further steps are done. Otherwise, OMX would be done in ad-hok way, and driven by technical and opportunistic factors.

Since teachers are well aware of content to be presented, and challenges that need to be overcome in helping students to understand certain topic, or lab exercise explanation, this activity should not take much time.

For script, for such a short video recording of few minutes, we need to have clear goal and it will be good to call students for action. Typically, for educational videos of this size, we can not have more than 100-120 words per minute, so up to 300-500 words total, and only if narrator keep talking all the time.

Much frequent case is that a lot visual information will be there, so narrator can deliver half of it, meaning that script should be limited to 200-300 words maximum, for OMX.

Having central figure in video shooting of OMX is a must-have, so rarely we may have two people in scene, perhaps depicting some action which requires extra hands.

Script should include text spelled out by narrator, or written on screen occasionally – hence it needs to sound well and clear, not on paper but in video recording. Typically simpler, clear statements without long sentences are more suitable.

A description of setup, narration and scenes / actions to be depicted in the clip are the minimum needed to start from.

Scene, duration	Video	Overlay, Graphics	Audio
1 000-010s	Setup, rotational view, beginning of experiment. Narrator close-up: DC motors are ubiquitous, from simple tiny devices, in wrist-watches to big, hundred of kW train engines	Showing trends in use of DC controlled motors from 2001 to 2020	Calm music
2 010-020s	No video, only narrator talking: Over time many variants evolved, customized for each important use case: step-motors, brushed motors, brushless motors, servo-motors, to name the few	Show classification table	Calm music

Storyboard

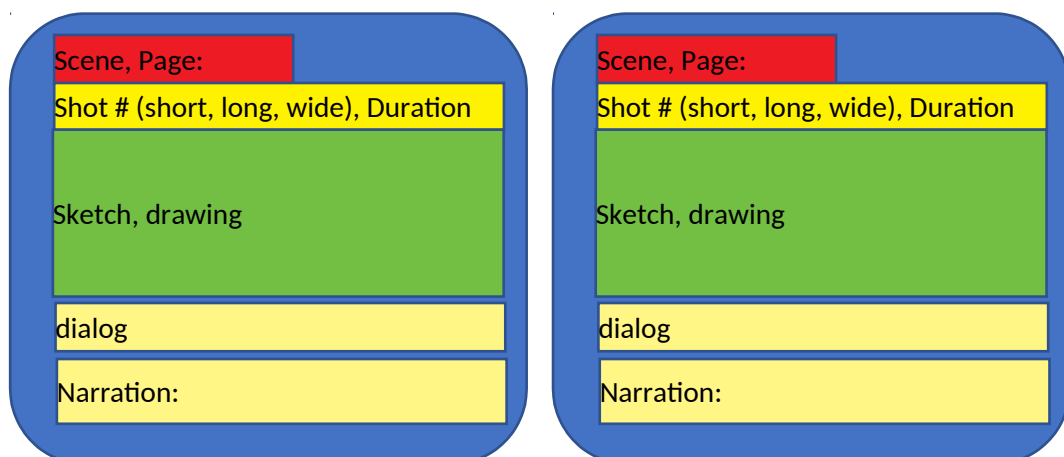
The OMX's storyboarding (storyboard sketch) means that we visually represent every shot of a RELAB "one-minute" video, using simple drawing or perhaps a dedicated software package. In that sense, it is visual depiction of previously written script, further elaborating all the details, and such it is a great input in planning activities, gathering/assembling equipment and setup itself.

If you prefer to hand-draw your storyboard, you don't need to draw boxes for every frame – standardize on template. Alternative, preferred way is to use open-source storyboard workflow, e.g. based on Story boarder and Fountain markup language. It can create PDF output with the storyboard, script too, for easy sharing and reviewing.

If you have decided to make the video, it is critical to have a plan. Shooting, editing, recording audio, producing graphics is very time-consuming and expensive, so planning the video helps you define your video. It tells everyone what shots will be required, what graphics are needed. Storyboard gives you a way to decide how you will split up your script into individual segments, to get better story overview. It may seem to be unnecessary extra step. However, it is good phase in the creative process to further clarify/visualize/modify your ideas by organizing images and text, and how to end video will be put together and help identify weak spots in the entire plan, so it can be addressed in early, pre-production phase. It can also bring up new ideas and reorganize available resources.

Storyboards may be created in a variety of ways, both digitally and manually on paper. You can use a computer, iPad, notecards, notebook, or even printer paper. So storyboard is a sequential description, in the chronological order, of the elements of the story such as images, text, narration, music, transitions, shots. Things to include in your storyboard:

- Boxes are read left-to-right.
- In each box draw the basic composition. Stick figures are sufficient.
- Indicate camera changes – pan, zoom in/out, focus rack
- Blocking (position and movement of the actors) should be indicated.
- Changes between shots (e.g. jump cuts, fades) should be indicated if important to the storytelling
- Follow scripts, and add notes for music cues, sound effects, and ambient noise.



Video Recording Equipment

This is an important element of successful live or AR type of material. They can purchased, borrowed or leased. Under video recording equipment, following items should be considered:

- Camera
 - Higher resolution WebCams
 - High-end Smartphone
 - DSLR cameras
 - Professional DSLR cameras
- Mounting equipment, like tripod, gimbal or dolly track
 - Other mounting platforms like drones or rail track are out of scope for these kind of recordings
- Lighting is natural ingredient of good recording.
 - LED panels
 - Umbrella Lighting Kits



Typically lab setups do not require battery power supply.

Cameras are most important piece of equipment. Following features, even in lower priced cameras, are desirable:

- HD recording
- Dual-pixel autofocus
- Face and object tracking
- External mic input
- Flipside screen
- Touch screen

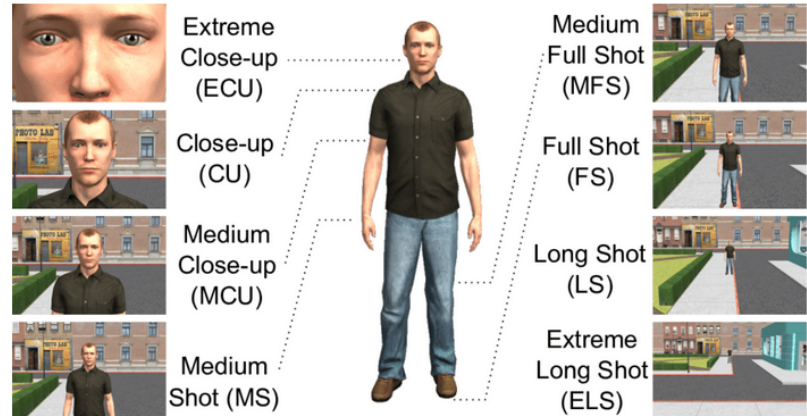
Higher end cameras may (should) have following features:

- 6-8k full-frame recording
- Shooting in 6k 10-bit quality at 24 FPS
- Anamorphic shooting
- Dual SD card slots
- Bluetooth & Wi-Fi connectivity

Video Shooting types

Here is list of some typical video shooting types, i.e. types of scenes recorded with the respect of scene coverage:

1. Extreme Wide Shot (ELS)
2. Long Shot (LS) / Wide Shot (WS)
3. Full Shot (FS)
4. Medium Long Shot (MLS) / Medium Wide Shot (MWS)
5. Cowboy Shot
6. Medium Shot (MS)
7. Medium Close Up (MCU)
8. Close Up (CU)
9. Extreme Close Up (ECU)
10. Establishing Shot



For OMX video content, typically Wide-Shot, Medium close-up, Close-up and extreme close-up are most useful.

Unless you are creating a series of video clips the demonstrator should be de-personalized, i.e. only the torso and arms performing the experiment should be framed during the exercise. If there is a group of related video clips, it is better to have same person being recorded, and narration can be more personalized. This helps creating better association of clips with the specific topic covered with the group of clips.

It is recommended that the entire equipment be shown in static frames, and that parts of the equipment be highlighted with zoom or special larger details during operation. It is recommended that the camera be static, or as a light panoramic movement (*schwenk*) that would follow the action of the experiment. Avoid free movement of the camera from your hand. Tripod or camera railtrack are useful pieces of equipment. If various angles of video shots are required, and if it is easier to do it from hand, consider procuring hand-help gimbal:



3D motorized hand-held gimbal



Smartphone gimbal

Avoid shooting with a strong backlight (e.g. if the window is behind the instrument / demonstrator. If this is the only possible shooting position, be sure to illuminate the experiment setting from the front / side, opposite the light source, placing the light source so as not to cast additional shadows.

During shooting, avoid fast panning or zoom in/out, fast scene changes, leave enough time to viewer to see, comprehend your content.

Video Studio setup

Video studio should be location where both video and audio recordings are created under controlled conditions.

This, optional, studio setup can be determined by logistical and financial constraints, so focus will be on affordable options. But, even modest setup need to be justified by the production level.

If usage studio is centralized, serving one big or several smaller educational institutions, it could be justified. But, if studio recording activities are rare (once in few weeks, or even less frequently), dedicated space for such purpose is probably not needed.

Organizing part of lab or office space as studio could be a way to go, but requires enough space, ~25-35m². It should be located in part of building without much background noise.

Studio should be equipped with good lighting, acoustic isolation (like acoustic foam), optional green wall to allow easier background insertion, or overlays in postproduction.

Many pieces of classic equipment can be replaced with desktop monitors or tablets, e.g. teleprompter, etc.

In some cases it might be possible to move lab setup to the studio and make recordings there. But more often, narrator or interview or discussion panel, can be recorded (video and audio), and inserted into overall recordings.

If there is justification for the studio, it is also worth dedicated separate, nearby space for video post-production, and storage space for mounting kits, lighting kits and camera equipment

Video recordings tech standards

We will focus here of details of video material created, like resolution, aspect ratios, frame rate and bitrates.

Resolution:

- Most, original recordings should be created in 1920x1080 resolution.
 - For dissemination, other resolutions should be prepared: 1280x720 and 640x360
- In some cases, 4K (3840x2160) recordings are also justified, especially if there are scenes with many important details
 - Recording created in this resolution should be also provided in 1920x1080 for easier dissemination, and let client decide based on presentation display and bandwidth

Frame rate:

- Frame rates 24, 25 and 60 are suggested. If very fast phenomenon is recorded, it is better to shoot at even higher frame rate, 120 fps, if your recording equipment allows it.

Color Dynamics:

- Typical recording equipment will produce 8 bits/pixel, per plane.
- But, in case where vivid colors with many variants are present, 10 bits/pixel (HDR) can enhance further picture quality. Still, both versions should be kept for dissemination since there are still many displays not able to render images of appropriate quality (hence 10 bits/pixel may not be justified).

Bandwidth:

- HD recordings of 1080p24/25 format can be prepared as 4-8Mbps . Range depends on type of scenes, how many rapid movements are in the scenes, are they often changed.

Codec types and tools:

- Using H264 Main Profile or H264 High Profile settings is advisable.
- VP8, royalty free Google codec is also worth considering, but licensing primarily applies to codec equipment vendors, not content creators.
- Codec H265 can achieve 30-50% bit rate savings, but at the expense of higher compute load.
- For off-line viewing, i.e. for pre-recorded clips, it is highly advisable to use two-pass encoding, B-frames should be enabled with I-frames intervals of 1-4 seconds

Multimedia container file formats

This is the file format allowing multiple data streams to be embedded concurrently into the file, along with some metadata.

Throughout years, many different formats have emerged, but at this point, few majors ones will be listed, and suggested for use:

- MP4 (file extension .MP4)
- MKV (file extension .MKV)
- WebM (file extension .MKV)
- HLS (groups of files, used for streaming)
- MPEG-TS (file extension .TS)

All the above formats can be handled using open source tools, with FFMPEG being the most important, and frequently foundation of other higher level software packages.

Streaming container formats

Most important streaming container solutions are HLS and MPEG-DASH. They are based on transfers of shorter video clips, split into independent video frames chunks, typical of duration of few seconds. In this way, latency problem is addressed, while preserving errorless data transmission.

E.g. converting of standard MP4 video clips to HLS can be done using open source FFMPEG tool. There are few steps, first being transcoding to multiple resolutions and bitrates. This step will create multiple shorter video clips.

Final step is creation of HLS Master Playlist (m3u8) that would allow client to adaptively select video clips based on network conditions.

Such formats can be done delivered over standard web sites with appropriate support, typically just on front-end side.

Webservers like NGINX can provide good scaling and response times to frequent (as elementary video clips are short) file transfer requests from multiple clients.

Augmented reality (AR)

It is an enhanced, or appended, version of the real physical world that is achieved through the use of digital, computer generated visuals and sound. In the context of educational video clips, primary purpose is to emphasize or clarify certain parts of an experiment or phenomenon that is described by the video.

Off-line AR

Insertion of text overlays or other graphic elements into video recording, could be done during video post-production. This is the easiest approach for static scene with constant orientation and field of view. Even time alignment of overlaid content can be done in interactive way. Transparency, color, font style and size, can be done interactively, and most video editors support this kind of effects. Kdenlive is one of them.

By applying perspective warping we can insert text overlays or even video into existing video recording. Here is an effect of video-in-video that was applied on top of tablet recorded in real-life:



Video-in-video with perspective warp



In order to simplify video post-production editing, it is possible to include more complex tools that would perform identification and localization of objects of interest. By using OI automatic determination of parameters for perspective warping, and area to be overlaid can be done, in off-line post-production process. Some simplification of this procedure can be achieved with the use of fiducials, i.e. 'QR'-like markers of special type, that can help in determination of camera pose and location as well as location of OI.

Based on that, overlay generation and mixing with the recording can be automated. A very powerful tool and the current industry standard for creating AR motion tracked overlays is by using adobe After Effects. This software follows similar principles as state of the art AR tracking in real time smartphone applications, but due to its post-production nature it is much more refined.

On-line AR

More challenging task is performing AR actions, overlays in real-time. This typically requires, AR helmet or goggles, but recently smartphone and tablet use have become popular too.



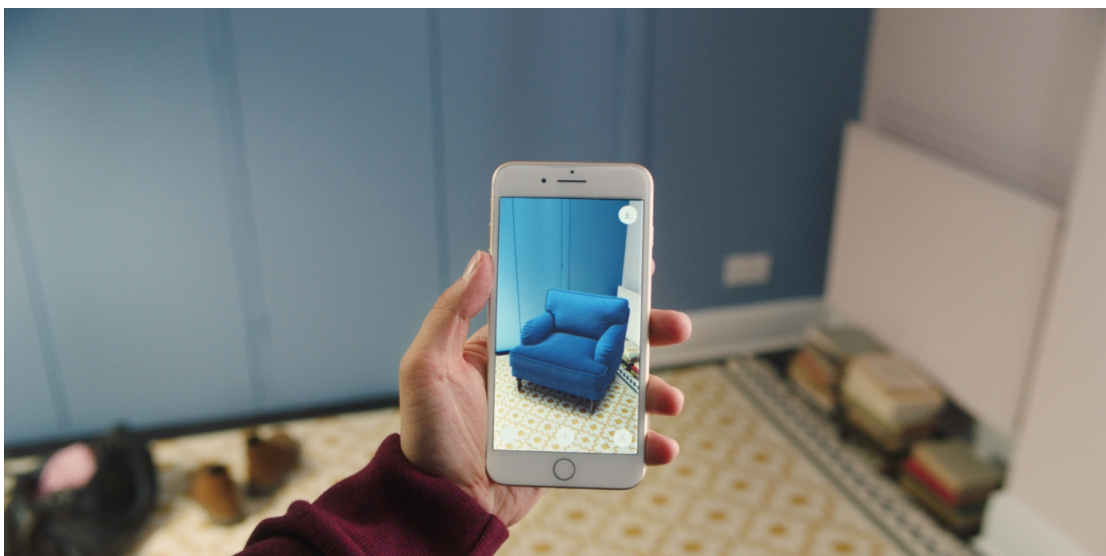
The approach is based on identification and localization of known objects, and identifying camera pose and location. Based on that text or graphics are warped and presented by the recognized object in real-time.

Generally the objects localized or tracked objects can either be fiducials or feature points of an actual image and they allow for very precise AR as long as the tracked objects are on screen.

One powerful tool for performing these tasks is open source computer vision library OpenCV, which includes APIs for object detection and localization, also fiducials detection and localization and finally APIs for homography parameter estimation. OpenCV is implemented in C/C++ but also includes Python wrappers allowing higher productivity approach at the expense of performance.

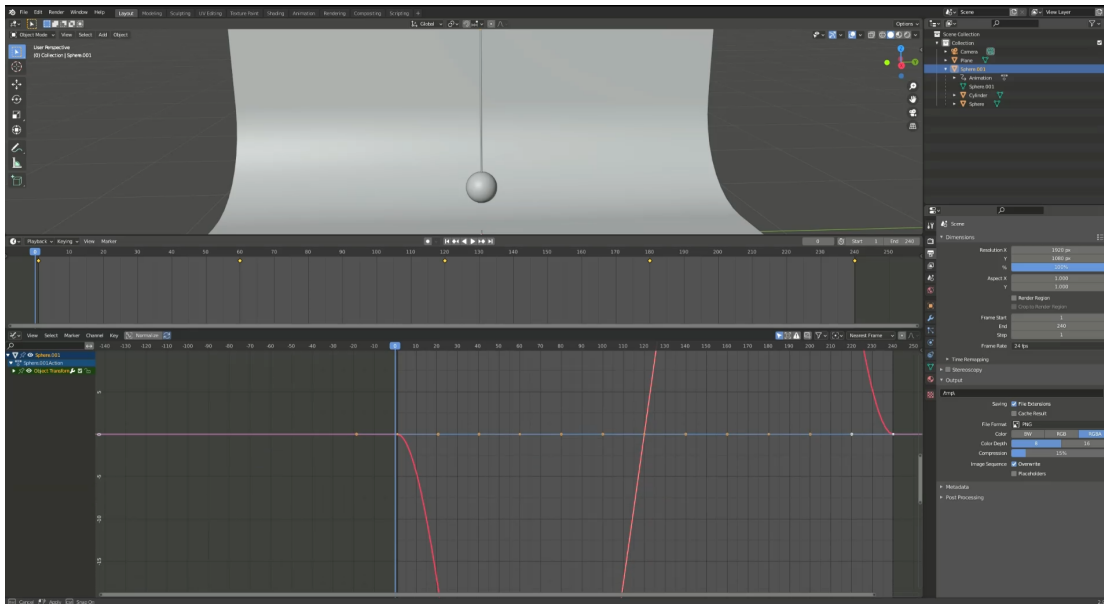
The other option which tracks the position of the camera itself is based on feature matching and mapping, this is less precise but allows for much closer to real AR applications. The main application for real time AR development is Unity3D. In the case of smartphones for instance, Unity has libraries like ARFoundation, ARCore and ARKit. The last two being the actual AR libraries for Android and IOS respectively.

Strictly speaking this is not related to OMX video creation, but it is worth mentioning that students would benefit from such interactivity, e.g. if they need to assemble lab setup, they could use a smartphone or a tablet to view lab setup pieces. Application could recognize objects are presented description, or even point to next step in assembly procedure steps , e.g. hook red connector to channel 1 of oscilloscope, etc..



Virtual reality (VR)

VR follows much of the same principals as AR. The main key difference is that there is no real world video or feedback directly tied to the virtual feedback. This means that there is no physical experiment that has an overlay to enhance the experience, instead the entire experiment may be virtual or recreated.



RELAB Video tutorial on how to create a VR physics experiment

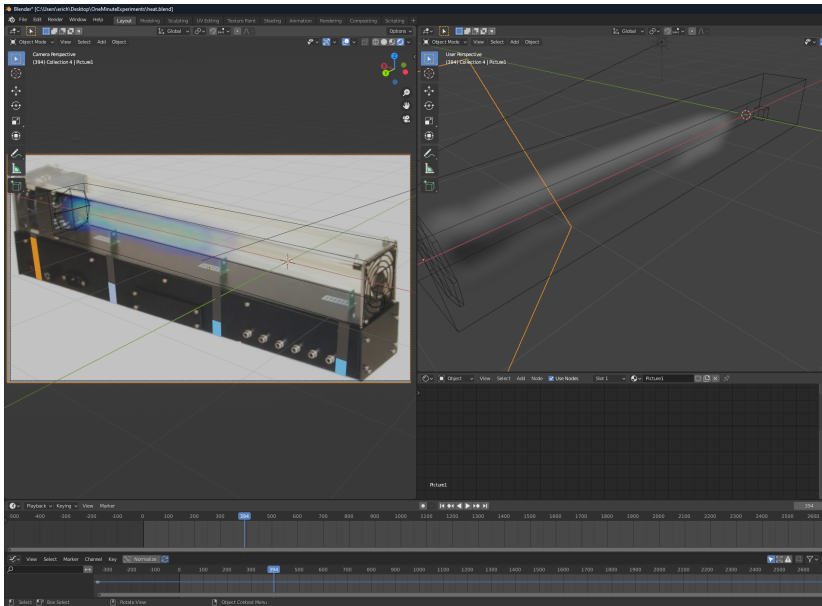
Off-line VR

The main method of creating fully virtual experiments is by first recording data about an experiment and then creating a plan of what the experiment should look like, include and how it should behave, just like storyboards in conventional animation.

One very widely used method of creating fully virtual videos and animations is by using 3D engines like Blender3D. This software not only allows the user to model 3D objects and scene pieces by hand, it has a python based scripting backend and the ability to animate and fully render any 3D elements that are in the scene.

In order to create a virtual animated experiment in an environment in blender, the experiment needs a scene and models. These can be imported or even hand made inside the editor itself.

Afterwards the objects in the scene need to be set to keyframes at specific points in time and their parameters changed in each keyframe to fit the experiment. In the case of the RELAB VR physics experiment tutorial video, certain keyframes had to be set with different positions of the pendulum in its swing. Adding these keyframe allows the editor to interpolate the intermediate frames and create a smooth animation between the different states.



All of these steps can be repeated for multiple objects and multiple parameters to fully animate any scene. The same general rules also apply when creating more complex animations like simulated air flow or water physics experiments.

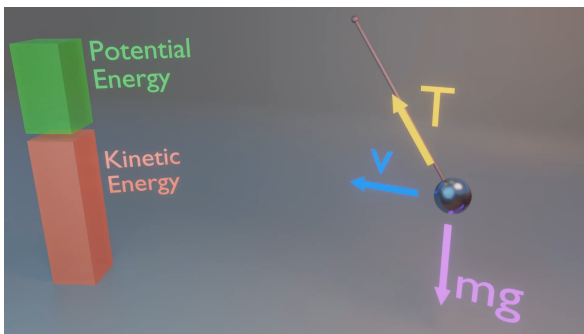
One thing to keep in mind about VR experiments is that however they are presented, they may be based off of real world data but they are fully simulated and will behave accordingly.

Creation of a VR physics experiment with simulated air flow

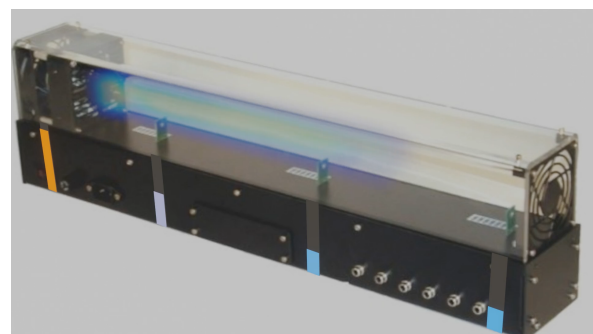
For additional information please refer to included video [icvVideo.mp4](#).

On-line VR

Real time VR applications don't face the same struggles as real time AR applications. The virtual mapping doesn't need to be as precise to get the full effect and it has been fully utilised on smartphones with things like GoogleVR well before the advent of smartphone AR.



RELAB VR physics experiment of the forces acting on a pendulum



RELAB VR physics experiment temperature changes

In terms of development platforms, the main two for VR development are Unity3D and Unreal Engine.

Post production, video editing

Post-production is very important step which may be the last, but it needs significant work effort, and for these kind of creation content, probably at least 50% of time.

Text overlays, mixing of video tracks, removal or reordering of portions of video clip, are just some of possible actions.

Open-source tools

There are many open source tools, with liberal licenses, to name the few: Kdenlive, OpenShot, Blender, Shotcut, Avidemux, Lives.

- Multi-track Video Editing
- All kinds of audio/video format supported with the help of FFmpeg libraries
- 2D Title maker
- Timeline preview
- Keyframeable effects
- Audiometer, Histogram, Waveform, etc.

Commercial tools

Some institutions may have already obtained licenses for commercial, high quality editing software, like Adobe Premier Pro (Windows) and FinalCut (Apple).

These are top quality products enabling high productivity and excellent results, but still, worth considering if video editing is frequently done. On the other hand, open source tools can produce great results too, perhaps with some additional time spent on learning and trials. If video editing is done intermittently, with constraint budgets, open source tools should not be treated as drawback.

Audio

Audio preparation requires careful planning. They can be done after video recordings are prepared, or typically some (never all) are collected during live recording.

Laptop or desktop, with external microphone and even higher quality smartphone are sufficient equipment for this step.

Live recordings, i.e. those done during lab experiment demonstration and during video shooting, require space without background noise or reverberation. In some cases, on-camera microphones are sufficient, but usually external directional microphones are better option.

Using a built-in mic on a camera should really be your 'last resort' choice for recording sound. It will usually be very small and is omnidirectional, in other words it will pick up ambient sounds from all around, literally a 360-degree coverage.

On camera microphones are sensitive enough to amplify sounds in its immediate vicinity, e.g. breathing or camera's lens motor noise. These downsides can be eliminated with external microphones: depending on ambient, in case we are doing recordings out of well controlled environment, dynamic microphone is preferred choice, comparing to condenser microphone which collects all sound inputs, in frequency range up to 16kHz or even 20kHz, and with lower frequency of 20-30Hz, typically attenuating <200Hz content.



Post-video creation, audio recordings should be always created in well controlled, studio ambient. Omni-directional microphones are valuable addition to the studio setup, providing excellent sound quality.

Noise reduction of the sounds originating in the studio (background noise, or speaker induced noise) can be also reduced with the

so called pop-filters



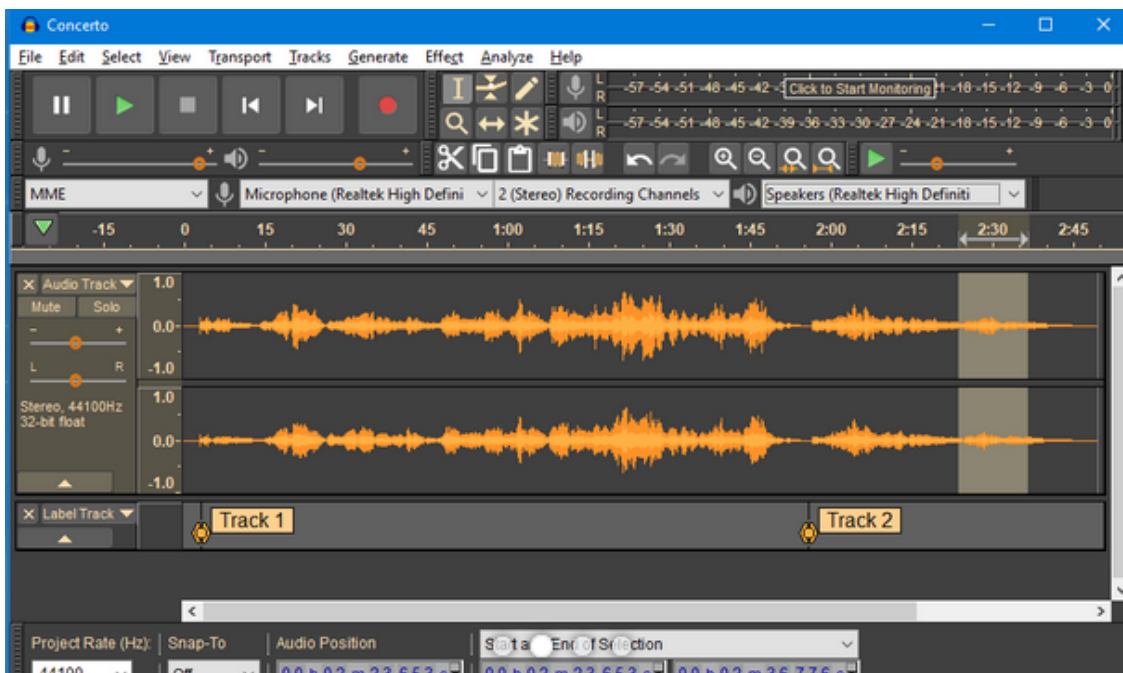
Regarding preparation of studio interiors with respect to audio recording concerns, after selecting quite room, windows, if present, should be covered and acoustic foam hanged on the walls.



Acoustic foam

Narrator may use written text, but need to follow timestamp prepared upfront, or write them down, so time alignment can be done more efficiently.

Open source software Audacity (GitHub available, cross-platform) is valuable tool for reviewing, filtering, mixing of audio clips. Tenacity is also open source, bit higher level software, perhaps easier to use, and built on top of Audacity.



Typical audio codecs used for higher quality material, are AAC (preferred) and AC3. Suggested bitrates are in 128-192kbps range.

Transcoding from other audio formats can be done using open source tools, like FFMPEG.

Final adjustments of video and audio tracks require good time alignment. Video editing software also provides tools to perform the task, and typically based on tracks: both audio and video.

Subtitling

Subtitles allow the content to be shared with a larger audience, either viewers who speak another language or those with hearing disabilities. It also makes the video easier to understand and helps the viewer retain the information better. Based on YouTube statistics, video clips with subtitles included, are viewed 15% more than similar videos but without subtitles.

To implement this feature, we need a file that contains the text and its respective timestamps, one of the most frequent formats being the SRT. Using the information from the file, subtitles are then encoded and ready to be used within the video.

SRT format is ASCII based, and easy to understand. At its basic level, even editors like Wordpad or Notepad++ could be used. Here is excerpt of one SRT file:

```

...
9
00:00:35,800 --> 00:00:40,822
Here is the beginning of experiment.
Additional attention is required.

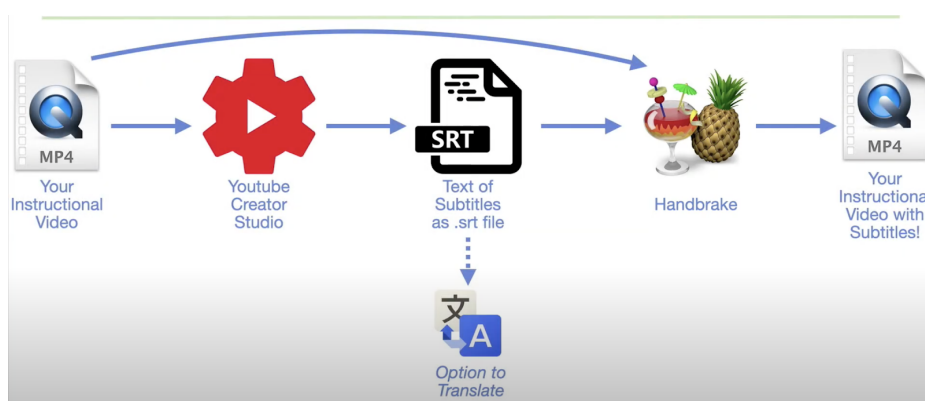
10
00:00:41,822 --> 00:00:44,400
Temperature need to be carefully turned increased.

11
00:00:42,400 --> 00:00:48,700
The process now starts.

```

Beginning of subtitle group (text overlaid once at a time) presentation is defined in seconds and milliseconds, with respect to start of video clip. Overlay is removed at second time instant. Font type and size are defined by the client, so SRT only carries text content.

One of the free tools often used is YouTube Studio because it allows automatic generation of the subtitles and timestamps. The output needs to be further refined, but it makes for a good starting point. Use of the free (GPLv2) Handbrake software is also necessary, for the subtitle encoding part.



There are other workflows, more standard: Recommended solution is based upon Subtitle Edit, multi-platform open source software, available on GitHub and released under GPLv3. It allows simultaneous review of media files, both video and audio waveforms, integrated into this software package, along with subtitle editor. Handy markers allow accurate definition of timestamps and easy editing of subtitle lines.

Subtitles (aka Captions) are important as they ensure that any words spoken along with any relevant sounds or sound effects are displayed on the screen so that people who are deaf or hard of hearing can read them. Without them, your video will not meet the necessary requirements for accessibility. But there is added benefit as someone cannot watch your video with the volume turned up (or watching in a loud environment, e.g. bus, train) or for anyone who wants to be able to read along to ensure they get any relevant spellings correct.

Note that closed captions (CC) rather than open captions (burnt-in) are better as they allow students to turn them on or off.

Subtitles can be overlaid and inserted as pictures (burnt-in) into video clips, performing specific watermarking. There are few benefits and many more downsides to this approach. Video players can be very simple not needing text rendering and overlay. A benefit that stopped being important many years ago, since most of video players easily does handling of SRT files. On the downside, by modifying video content, titles cannot be turned off during viewing, potentially obscuring interesting parts of video clip. Also, there is no good way to create subtitles in different language. FFmpeg tool (open source) can easily perform subtitle 'burn-in' into video clips – if needed for any reason.

Multi-lingual

This can be done with additional audio tracks and subtitles. During clip preparation it is better to keep audio tracks and/or subtitles in separate files, allowing final mixing and combining multiple tracks into single container format.

Translation of subtitles, typically in ASCII SRT format can be done offline, just replacing each sentence in language A with sentence/line in language B. We can preserve timestamps from the lead language (English typically) and reused that from translated subtitles.

Translated subtitles can be used during dubbing process and with the teleprompter software capable of reading SRT files.

Translating options for multi-lingual content preparation

- Machine translation: good as a starting point, but need further, human refinement, nevertheless valuable as it may reduce translation time significantly.
 - Google Translate
 - DeepL
 - Linguee - online context dictionary
 - MyMemory - translation memory base
- Human-Machine translation
 - Crowdsourcing translation platforms, e.g. Tatoeba
- Human translation

Audio Dubbing

While having subtitles is cheaper and simpler, one of the upsides of having the video dubbed is that the viewer will enjoy more and understand better the content that is spoken to (or her) in his own language or dialect. The obvious downside is extensive human engagement which is costly and not easily scalable.

One handy open source tool is GitHub's hosted Audicity (GPLv3), which will allow to have full control on recording process, including editing and effects insertion. By following continuously available timestamps, existing narration from subtitles, can be used to guide the speaker appropriately.

Audio track editing, like clipping, applying effects, reordering can be done in video editors too, allowing fine adjustments.

This approach can also help in multi-lingual dissemination ensuring wider audience.

Dissemination (platforms, metadata)

Dissemination of video clips for educational use of this type, would be primarily done via University Web sites or servers, integrated with other eLearning platforms like Moodle.

Since video clips are static objects, this is primarily executed as dedicated file transfer. In rare cases, when video recording is prepared in streaming format like HLS or DASH, stream of files of short duration is prepared is delivered to client platform/application (student's side). Important benefit of this approach is reduced latency, and real-time adaptation of delivery/consumption mechanism to varying network conditions.

On university websites material need to be organized at least on per area/topic basis, so they can found easily while students are looking for material based on instructions and not explicit URL. Some search mechanism including keywords (metadata) is desirable.

Another important aspect is available bandwidth for download. Having multiple concurrent video sessions can quickly overwhelm available university public internet connection: e.g. 100 download sessions at 5Mbps each will saturate 1Gbps public connection. Hence, having same video material, transcoded in few formats, and allowing automatic adaptation per bandwidth conditions, is needed.

Public platforms for video content dissemination can be valuable tool, most notable being Google's YouTube. Others are Vimeo, DailyMotion, Utreon, VideosHub.

Primary benefit of these platforms is scalability and ability to serve many concurrent video sessions. Typically they require registration for content creators, and following certain technical standards that are automatically verified. Strict copyright and ethical standards are also enforced on these platforms.

Open source tools available on GitHub, like OBS-Studio (GPLv2) can help in final preparation and publishing of OMX video clips on some of these platforms.

An example: Installation of a set to produce audiovisual and multimedia resources

Brief orientation

In this section, we will see what needs we will have to satisfy when facing the installation of a semi-professional set where we can produce the audiovisual and / or multimedia material that we need as educational resources.

We will see dimensions, technical resources, recommendations, and other data of interest that will guide us in order to be able to install all the necessary equipment in an adequate environment to achieve the best results.

Introduction

The first thing to consider is what we are going to need to produce the material. In this sense, the first thing that usually comes to mind is the video recordings and other educational resources that complement the teaching activity.

But what kind of activities are we going to do? Video classes? Lab experiments?

In our case, we will opt for a particular configuration that is the one that best suits the objective sought: the recording of lab experiments.

And that configuration will consist fundamentally, on the one hand of the possibility of **synchronously** recording the image of the lab equipment (**camera**) and, on the other, a recording from a **computer** screen, in such a way that we have a video with a basic composition of the image of a teacher in the first term and the computer application that is using in the second term. We must bear in mind that the computer application can be anything that has output from a computer, that is, a Power Point presentation, a web page, another video, any office tool, a user interface that allows manipulating a lab equipment, etc. For some experiments, though, no computer support is needed. In those cases, of course, only the first element is required, and can be considered as a subcase of the one presented here.

This will be the objective that we have to achieve when we face our installation: to obtain a video in standard format (mp4 for example) with the composition described.

The System

Basically, to obtain the desired results we will need, on the one hand, to obtain the recording of the live experiment, through a camera, and on the other hand the VGA output of a computer, tablet or even smartphone (adapting the outputs of the latter to a VGA output).

Both signals, the camera, and the VGA, must be synchronized so that they can be reproduced simultaneously in real time and that there are no asynchronies between what is happening in the experiment and what is shown in the computer application in the second term. For this, we will need a unique system that can receive the two signals, recording them, synchronizing them, and storing them. Finally, we will need a system that is capable of, through a luminance key ¹, mixing both images in one and producing a final video with a standard format and with the two images joined.

As we have already been anticipating, we already have a series of basic components for our system:

- ⌘ A video **camera** with sufficient resolution that will be the one that captures the image of the teacher while exposing his subject
- ⌘ A **microphone** or audio system that allows the experiments' sounds to be clearly collected.
- ⌘ A **computer, tablet, or smartphone** with output adapter to VGA from where the teacher either exposes the material that will further explain the experiment or operates the lab interface.
- ⌘ A **white background**, with a white whole as pure as possible that will serve as a reference to later be able to make a luminance key.
- ⌘ An adequate **lighting** system to be able to obtain a good image of the teacher and a target as saturated as possible to make the luminance key.
- ⌘ A **recording** system that can record the two signals (camera and VGA) synchronously and storing them
- ⌘ A **composition** software that allows you to join both signals in a single video using a preconfigured template
- ⌘ A video **editing** software that allows us to edit the videos obtained in order to add or remove parts.

With all these components, we can configure a diagram like the following:

¹ Luminance key is a process by which a white background is replaced by an image or sequence of images to form a video with the two signals mixed. The luminance key replaces the white of the main image with the images of the secondary, as opposed to the chroma key or chrominance key that what it does is replace a vivid color (usually a type of concrete green) with those secondary images. That is, for a luminance key we will use a white background that will be substituted, and for a chrominance key, a green background.

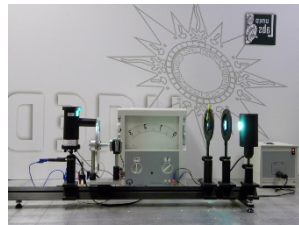


Image Software



Experiment Camera Compositing



Synchronous signal recorder

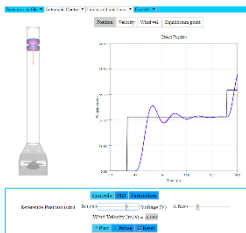
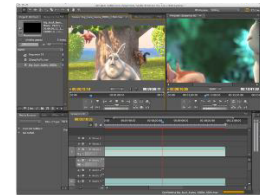


Image Editing software



Computer App Video



Set Requirements

We will need an adequate space to be able to carry out the recordings to generate audiovisual pills of the type we are dealing with.



Room Requirements

Essential requirements:

- **Dimensions:** 5 x 7 meters or more
- Be **soundproofed**, or at least be in a place free of external noise both on the sides and up and down. Away from passage corridors or rooms where people usually gather.
- Have a low level of **reverberation** (having false floor and false ceiling or carpeted floor, adequate curtains to reduce reverberation or shelves).
- It must be a room **without windows** or at least that these can be completely darkened.
- It must have enough electrical outlets and enough electrical power to be able to connect all the equipment that will be necessary.

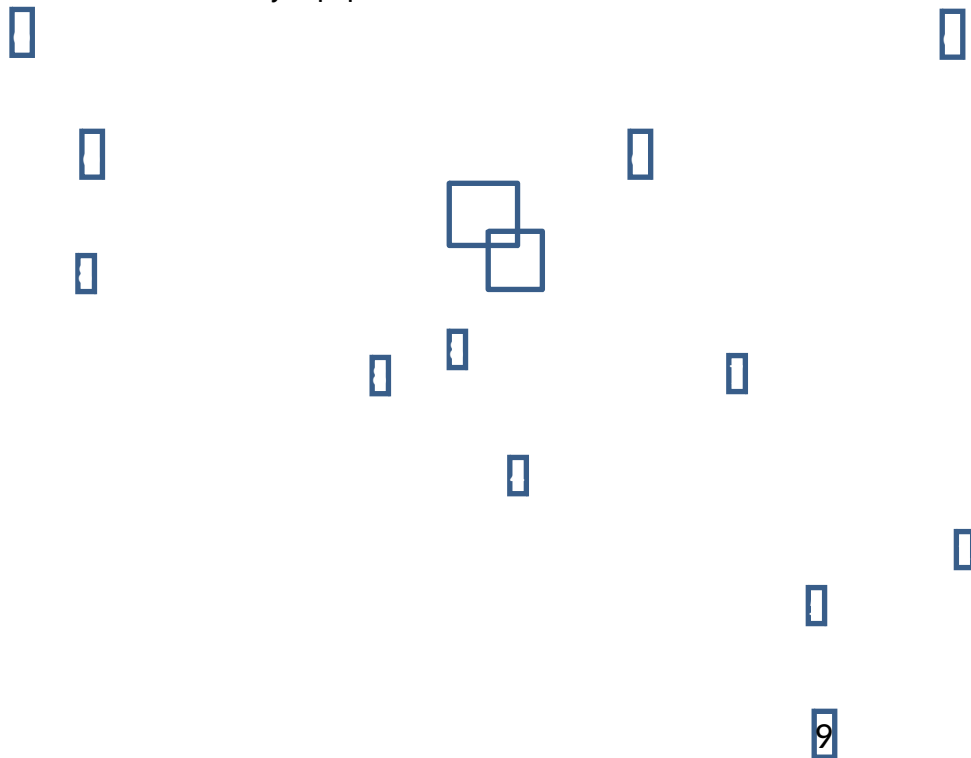
Recommended requirements:

- Have air conditioning (7,000 to 10,000 refrigerators).
- Have an Uninterruptible Power Supply (UPS).

Installation subsystems

In this installation we will consider several subsystems:

- Recording
- Audio and video
- Lighting
- Presentation
- Auxiliary equipment



Recording and technical control subsystem

- Recording system of the two signals (camera and VGA output) Software of composition of both signals

Video Editing Software

This system, normally managed by a specialized technician, will be the one that allows the synchronous recording of the two main signals (camera and VGA output), the subsequent processing of both signals to produce a single one with the combination of the two, and a video editing software that allows the subsequent post-production of the finished piece.

Proposed equipment:

- For synchronous recording:
 - Gallicaster ®
 - Adobe Captivate ®
- For the processing and mixing of the two signals:
 - POLIMEDIA (development of the Polytechnic University of Valencia) ®
- For video editing
 - Adobe Premiere ®

Audio and video subsystem

- Video camera for capture speaker.
- Microphone. The picture shows a unidirectional microphone from the camera itself. It is the most economical and technically simple solution, but a wireless or non-wireless lapel microphone that is also connected to the camera is recommended. With this type of microphones, we avoid interference and other noises that may sneak into the recording.
- Camera Tripod.
- Audio mixer.
It would also be advisable to have headphones so that the technician can listen to the recording.

This subsystem allows the live capture of both the image and the audio of a speaker (if present) in real time.

Proposed equipment:

- ⌘ For image capture:
 - Professional or semi-professional camera with XLR audio input.
 - Manfrotto ® tripod or similar.
- ⌘ For audio capture:
 - Sennheiser ® tie microphone or similar.
 - Semiprofessional audio mixer.

Lighting subsystem

- Cold light bulbs in Led or neon and their supports to the wall

This subsystem is used for the lighting of the background to obtain a target as saturated as possible and the teacher to avoid shadows.

To this end, 4 cold light bulbs are available (preferably LEDs) since being a small room you must avoid the heat that gives off high power bulbs and that are not of this type.

Two spotlights (of more intensity) would be placed to illuminate the white background in a support (bar) from wall to wall or in individual tripods and the other two (of less intensity) would be placed in front of the position of the teacher to illuminate him, they would also be fixed in wall-to-wall bars or in individual tripods.

The advantage of the bar over tripods is that it does not take up space in the room. Tripods can limit mobility quite a bit because with their extended legs they take up quite a bit of space. The effect is the same.

Proposed equipment:

- For rear backlights:
 - FLUORLIGHT JMF 4 x 55 W display
- For the speaker's light bulbs:
 - 2 x 55W ICE Ianiro display

Presentation subsystem

- Computer that will contain the teacher's presentation/app and whose VGA output will be captured in real time and synchronous with the image captured by the teacher's camera. It can also be another device type Tablet or Smartphone if the output is compatible with the VGA system through any adapter for that purpose.
- Presence monitors where the presentation will be projected so that the teacher can follow it.

Proposed equipment:

- ⊗ For the presentation:
 - Computer through which the presentation is handled, or the lab computer application is manipulated. It will have a wireless keyboard and mouse from which the teacher will manage it from his lectern. It can also be a Tablet or Smartphone.
- ⊗ For monitors
 - A monitor of approximately 24" that will be located just below the video camera lens
 - A monitor of approximately 42" that will be located on the right side of the Rapporteur.
 - Both will have VGA input.
 - VGA signal distributor to connect the two monitors to the computer.

Auxiliary equipment subsystem

- It is the rest of the kit that completes the set:
 - ⊗ Roll-up background in white vinyl (very saturated) that can be extended on the back wall, behind the speaker. You can also paint the wall with very saturated white, but vinyl gives better results.
 - ⊗ Support for white background.

- ⊘ Lectern and high bench for the speaker.
- ⊘ Table and chair for the technician.
 - ⊘ Desktop computer with two monitors for the technician and that can monitor the recording. On this computer will be installed the software for the combination of the two signals (i.e. POLIMEDIA ®) and the software for video editing (i.e. Adobe Premiere ®).

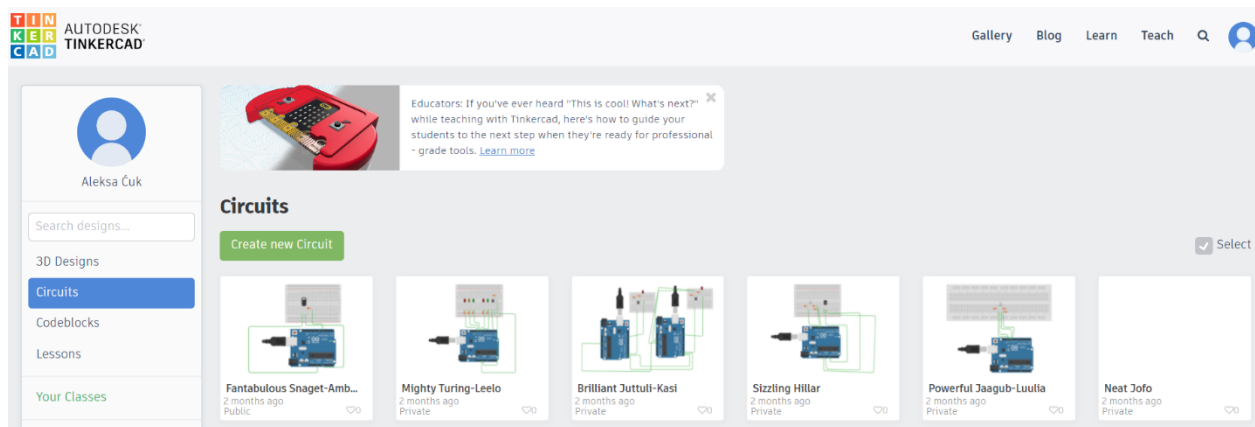
With this subsystem, the room technician will be able to monitor the signal, carry out the process of integrating both signals (with the POLIMEDIA ®) and if necessary, do the required video editing with Adobe Premiere ®.

A first hand experience in “one minute video experiment” creation process

Description

The topic of the first set of laboratory exercises videos is digital inputs and outputs and work with switches and LED diodes. The goal of these exercises is to introduce students to working on the Arduino. The video materials that will be provided are sorted according to the degree of complexity from simpler to more complex. The main goal is for students to get familiar with the way of designing and solving problems with the help of Arduino. The goal of the first set of exercises is to acquaint students with the way of thinking, what is needed to solve a certain problem, what the scheme of the final problem looks like, how all components are connected in one system, how to write good and functional programming code and finally the output or look of final solution.

The first video explains the way in which all future exercises will be done. All the advantages of using an online simulator to work with systems such as Arduino are explained. In the video materials, all exercises will be done with the help of the Tinkercad platform.



Each exercise will be divided into 2 parts. The part 1 will describe the problem we want to solve, the schematic representation of the solution as well as the connections of the components. The part 2 will deal with writing the program code of our solution.

Exercise I - Diode Blinking

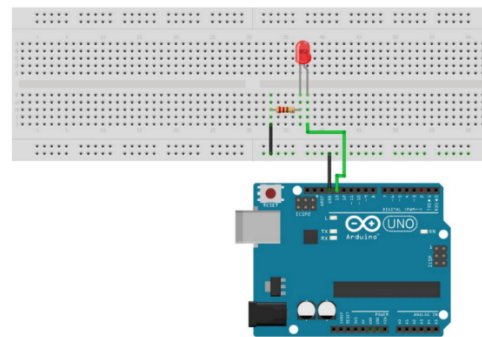
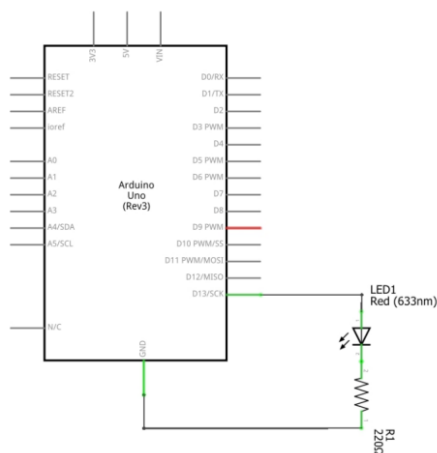
The goal of first exercise is to Implement an Arduino system that uses a single diode. The diode should flash with for a period of 0.5 seconds.

Solution:

In order to realize this system, the following elements are necessary:

1. Arduino UNO
2. Resistor 220Ω
3. Diode
4. Breadboard

Part 1 video describes the problem, shows the solution scheme and how to connect all the components. In this example, the necessary components are 1 Arduino UNO, 1 resistor 220Ω, 1 LED Diode.



Part 2 video show the code implementation of solution. First we need to initialize necessary variables. PinNo needs to be set to 13 since we used digital pin 13 to connect diode. DelayTime is variable that will be used to set period of diode blinking, and at the start of program diode is turn off so we set DiodeStatus to LOW. In setup() function we first initialize diode pin as output pin, and then we set initial diode state. In loop function we are changing diode status. With digitalWrite() function we are displaying output value on diode. And with delay function we delay program execution for desired time.

Exercise II - Diode and button

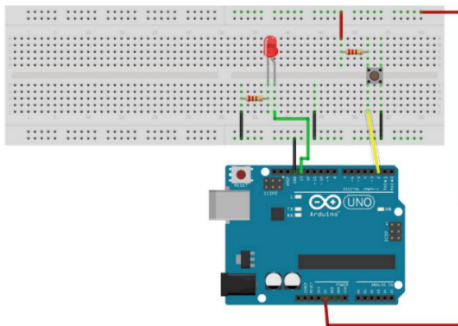
The goal of exercise is to implement an Arduino system that turns on the diode if the button is pressed while otherwise the diode is inactive.

Solution:

In order to realize this system, the following elements are necessary:

5. Arduino UNO
6. 2x Resistor 220 Ω
7. Diode
8. Breadboard
9. Pushbutton

Part 1 video describes the problem, shows the solution scheme and how to connect all the components. In this example, the necessary components are 1 Arduino UNO, 2x resistor 220 Ω , 1 LED Diode and 1 Pushbutton.



The diode is connected to a digital pin 13, whose voltage level can be adjusted and controlled diode operation, while the key is pinned to pin 2. The Status variable contains the current state of the button. In setup function, the diode pin is configured as an output pin, while the key pin is configured as an input pin. In the loop function, the input value of the key is read and assigned to the Status. If the key is pressed, the diode turns off, and if not, the diode turns on.

```
1  const int PIN_DIODE = 13;
2  const int PIN_BUTTON = 2;
3  volatile int STATUS = LOW;
4
5  void setup() {
6      pinMode(PIN_DIODE, OUTPUT);
7      pinMode(PIN_BUTTON, INPUT);
8      digitalWrite(PIN_DIODE, STATUS);
9  }
10
11 void loop () {
12     STATUS = digitalRead(PIN_BUTTON);
13     digitalWrite(PIN_DIODE, STATUS);
14 }
15
```

Part 2 video show the code implementation of solution. First we need to initialize necessary variables. The variables PIN_DIODE and PIN_BUTTON are set on digital pins 13 and 2 r. The DIODE variable defines the pin to which the button is connected, while the Status variable carries information about whether the button was pressed. Within the setup function, the system is initialized. The pin directions are set first. The pin to which the diode is connected is set as the output, while the pin to which the button is connected we set as input. The initial value on this pin is "0". Within the function loop, the value is constantly read from pin number 2 to which the button is attached writing the inversion of the read value on the digital pin number 13 to which the diode is attached.

Conclusion

This first set of videos is a logical group of materials that show the basic concepts of working with an Arduino device. The exercises that have been done are a good starting point for continuing work on this topic. We covered topics related to digital inputs as well as work with buttons. These videos introduce the student to the process of thinking, working with hardware and working in an online environment. The videos are structured in such a way that the student can quickly and relatively easily understand a certain problem. The videos are divided into 2 parts. Reason why the videos are divided is to be as effective as possible. Also, the division into 2 parts leaves the student with the possibility to easily return to a certain part that may not understand well. In the future of these exercises, a little more complex tasks will be done, which will have a focus on certain topics necessary in the development of Internet of Things.