
Your Paper is Dead! Bringing Life to Research Articles with Animated Figures

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***Please Note:** *This article contains numerous animated figures and is best viewed in Adobe Reader X or higher.*

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Abstract

The dissemination of scientific knowledge has evolved over the centuries from handwritten manuscripts transcribed and published as physical black and white prints-on-paper, to digital documents in full color available for consultation online. Even if it now primarily relies on digital media, academic publishing still generally adheres to its historical rigid paper-based style—where static content is presented at the ready-to-print letter format. In this paper, we reflect on our experience of authoring a published academic article that embeds an *animated figure* and discuss the opportunities and caveats of transitioning to such practice at the wider academic literature scale.

Introduction

The old adage “*a picture is worth a thousand words*” refers to the belief that, in some cases, a static image can better communicate an idea than written text. Scientists have long recognized this idea, and have been including charts, drawings and photographs in their research articles even before the availability of desktop computers and document editing software (Figure 1). Similarly, one could argue that a video or animation can, in some cases, be more effective at expressing a concept than a static image [11]. This is especially the case in research areas such as Human-Computer Interaction (HCI) and Computer Graphics, which deal with animation and interactive systems.

The *Journal of Image Guided Surgery* (1995) was the first peer-reviewed journal to offer an electronic version of its articles when bandwidth allowed quick download of files, later followed by many other journals [16]. With digitization, color figures became commonplace. However, in spite of such shift—and contrary to early predictions [14]—articles have kept their print-based nature. Adobe’s PDF emerged as an efficient way to electronically deliver print-based documents in the early 1990’s. Similar to its predecessor PostScript, PDF is based on vector graphics and optimized for printers. The PDF file format since became the standard format thanks to its greater portability over HTML at the time, and its wide adoption in the production workflow [16].

In parallel, auxiliary material in the form of video figures developed in scientific branches such as Computer Graphics and HCI which deal with interactive systems. Similar to paper submissions, multimedia material was initially mailed on VHS or disks. As digital video file formats matured, such videos could be submitted using electronic web-based systems. With rare exceptions, such as JoVE [8] which (exclusively) publishes scientific contributions as videos, the vast majority of conference and journal publications detach the multimedia content from the actual articles, even though embedding rich media in PDF files has been available since as long as ten years ago [1].

While no model has yet imposed itself, diverse scientific communities are putting efforts to make academic publications interactive and open access. The Optical Society of America and National Library of Medicine at NIH jointly developed “interactive science publishing” (ISP), a software for authors to organize and publish source data in scientific articles [2]. 2D/3D data figures

can be viewed and analyzed interactively by the reader using the software. In a similar vein, the Collage European research project [5] allows e-scientists to author actual executable papers, where methods can be executed, analyzed and evaluated by the reader.

In 2014, we published *Draco: Bringing Life to Illustrations with Kinetic Textures* [9], which may be the first scholarly in the ACM digital library that embeds an *animated figure*. The following section defines this form of multimedia component, which we argue should be more utilized in scientific articles, and outlines the step-by-step production workflow we used.

Animated Figures

While PDFs support the broad use of videos and interactive Flash objects, special care must be taken in the integration of such formats within a scholarly research article. In particular, there should be minimal disruption to the typical reading experience. This means a reader should not be burdened with complex UI controls. Equally important, readers should not be distracted by the animation when reading text. As such we propose the use of *animated figures*:

Definition (Animated Figure):

A short autonomous and continuously looping video that enhances what would otherwise be a static figure or set of figures (Figure 2).

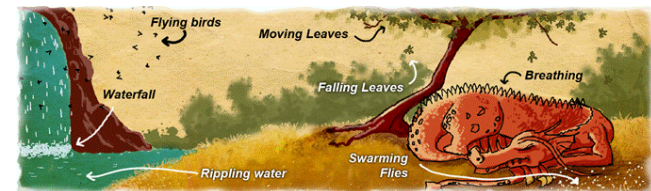


Figure 2. Animated banner image as found in [9].

In Camtasia Studio 7:

1. Use Camtasia 7 to convert the video to an .flv file

In Adobe Flash Professional CC:

1. Create new project with correct dimensions
2. File→Import→Import video
 - a. Choose embed flv in timeline
 - b. Set symbol type to movie clip
3. File→Export→Export movie

Figure 3. Instructions to convert a video file into a looping *swf* file.

In Adobe Acrobat Pro:

1. Tools → Interactive Objects → Add SWF
2. Drag the cursor over the exact bound of the static image in the PDF
3. Show Advanced Options
 - a. Enable When: The page containing the content is loaded (*automatic*) OR The content is clicked (*manual*)
 - b. Disable When: Disable is selected from the context menu
 - c. Playback Style: Play content on page
 - d. Create Poster From File (load your blank transparent image from Step 3)
4. Adjust the size and position of your video, so it perfectly overlays your static image.

Figure 4. Instructions to embed an *swf* file into a PDF file with Adobe Acrobat Pro.

In some cases, playback for animated figures can be automatic, meaning the animation will play by default when the PDF is opened. This is appropriate for animations that have subtle motion [9]. For animations with more noticeable motion, playback should be manual, allowing the reader to start and stop the playback on-demand, to avoid distraction when reading close-by text.

Process and Instructions

The following steps outline the process used to create and embed an animated figure (Figure 2). Please see our appendix for example files and tutorial videos¹.

1) Create a video

The original video to be embedded as an animated figure within the PDF can be created in any format. Appropriate steps should then be taken to make the loop from the end to the start of the video as seamless as possible. When this is not possible, the original video can be modified so that there is a short cross fade between the first and last frame to avoid an abrupt visual jump.

Alternative options for creating seamlessly looping videos include video morph, which typically relies on image distortion techniques, and video textures [15] synthesized from the random rearrangement and blending of the frames from a source video. While both approaches enable the creation of aesthetically pleasing results, the produced video depicts content that is either spatially (morph) or temporally (video textures) distorted, which may not always be appropriate depending on what the figure is meant to illustrate.

¹ <http://www.autodeskresearch.com/publications/animatedfigures>

Once this new video is produced, a preview of the looping effect that will occur within the PDF can be obtained by enabling the loop feature of any standard media player.

2) Convert the video to *swf*

In order to embed the video into a PDF file, it needs to be converted to a looping *swf* file (Adobe Flash file format). We first use Camtasia Studio 7 to create an *flv* file, and then create the looping *swf* in Adobe Flash CC. The associated steps are detailed in Figure 3.

3) Create a static PDF

A traditional document editor (e.g., Word, LaTeX, etc), can be used to create a static version of the PDF. A static figure should be placed in the position where the animated figure will appear. This image should be an appropriate static representation of the animated figure, to ensure that the article is still self-contained when printed on paper or when the video is disabled.

In our case, we used a still frame of the video with callouts to the animation effects (Figure 5). In some cases, it may be better to omit the callouts – that will depend on what the figures is communicating to the reader. An icon or border can also be added if manual playback will be used (Figure 6).

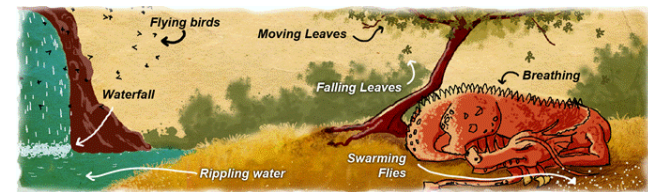


Figure 5: The static representation of our animation includes callouts, in place of the actual animation effects.

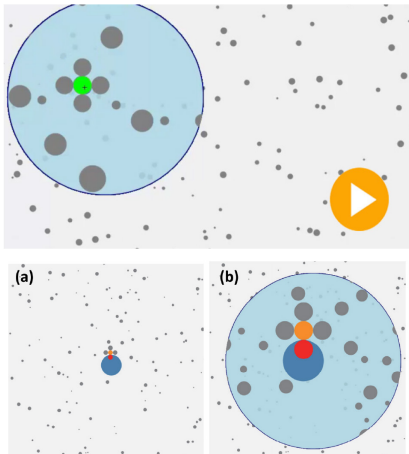


Figure 6. Top: Mott and Woobrock use a sequence of static images to demonstrate the behavior of the Bubble Lens [12] technique. Bottom: An animated figure may better convey the dynamics of the Bubble Lens technique.

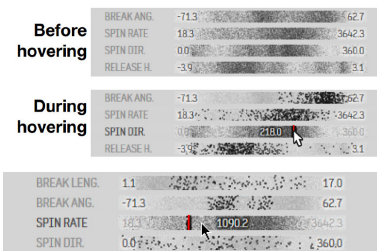


Figure 7. Top: A sequence of static figures is used to show how two components in this visualization are coordinated [10]. Bottom: An animation better conveys the dynamics of the coordinated effect.

3) Create a blank transparent image

When the animated figure is added to the PDF, a “poster image” will be specified, to be displayed in situations when the video cannot be rendered or is disabled. To efficiently and robustly handle this case, we create and use a blank transparent image. As such, if the video does not load or is disabled, the reader will see the underlying static image you have created (see Step 2 above).

4) Embed the swf file into the PDF

Now comes the fun part! The animated figure is added to the PDF file by editing the PDF using Adobe Acrobat Pro, following the steps described in Figure 4.

5) Enjoy your new animated PDF!

Congratulations! You are now the proud author of an animated PDF. Any time the PDF is opened, the video will begin to play and continuously loop automatically.

When manual playback is used, readers click the image to begin playback. In both cases, readers can right click the video and select “Disable Content” from the context menu to disable playback.

Sample Use Cases

We believe there are many use cases when animated figures will be a valuable addition to a research article. In our case, we were conveying an animation that the system being described in our article could produce. Below we categorize the primary use cases for animated figures, beyond our own example. We use actual example static figures from a range of published HCI and Graphics research papers, and show how such figures could have been enhanced as animated figures. In the following examples we use both automatic and

manual playback implementations, depending on the natures of the animations. Figure with harsher animation effects use manual playback.

Demonstrating How an Interaction Technique Works

Often papers that describe interactive systems or interaction techniques must use a sequence of static figures to represent the nature of the interactions being described. In such cases, an animated figure could better convey the actual dynamics to the reader. For example, Mott and Wobbrock use two static figures to describe a behavior of their Bubble Lens technique [12]. Alternatively, an animated figure could have been used to help convey this behavior (Figure 6).

Illustrating Coordination with Visualizations

Animations may also be useful when there are coordinated dynamics between two components of an interface or visualization. For example, Matejka et al. used two static figures to show how data points in one scatter plot are highlighted when the user hovers over data points in a different scatter plot [10]. An animation is much better at conveying the dynamics of this coordinated effect (Figure 7).

Contrasting Visual Differences

An animated figure can also be useful for contrasting two static figures that may have subtle differences, for example when comparing the output of a multiple rendering algorithms or the results from a user study. In PotraitSketch, the authors display an image with and without their proposed stroke correction algorithm applied [18]. When displayed side by side, it is hard to detect all the visual differences. An animated figure could help show how the images differ (Figure 9).

Candle flame. A 33-second video of a candle flame was turned into four different video textures: one random play texture; and three different video loops, each containing three different primitive loops. One of the video loops repeats every 426 frames. The other two repeat every 241 frames; these each use the same set of three primitive loops, but are scheduled in a different order. In the figure at right, the position of the frame currently being displayed in the original video clip is denoted by the red bar. The red curves show the possible transitions from one frame in the original video clip to another, used by the random play texture.

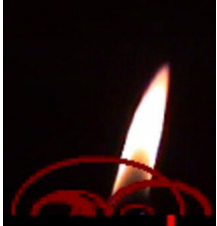


Figure 8. Top: The Video Textures authors used a static frame from a video, and a long caption, to try to explain an animation [15]. Bottom: An animated figure can be used to precisely demonstrate the animation effect.

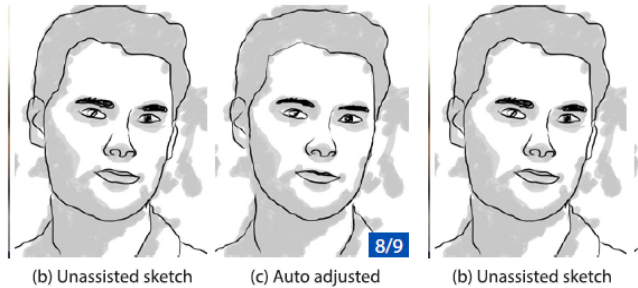


Figure 9. Left: Xie et al. [18] use two static images as side-by-side comparisons, but the difference in b) and c) are subtle. Right: A single animated figure that fades between the two images makes it easier to notice the differences.

Displaying an Animation

Maybe the most obvious use of an animated figure is to depict an animation effect which a research paper is describing. This was the use case for our Draco system. Depending on the nature of the animation, it may be difficult or impossible to adequately communicate such animation effects with only text and static images.

For example, when describing their Video Textures technology, Schödl et al. use a single static video frame, and a long-winded caption, to represent a short looping video sequence [15]. This is another clear case when an animated figure would much better convey the concept to the reader (Figure 8).

Another example is seen with Glimpse [6], which animates from markup documents to the corresponding rendered documents. The authors used a space-consuming sequence of three images, each of which composed by blending several blurred versions of successive frames from the animation into the same static image to convey dynamics. Alternatively, a looping video could have been used (Figure 10).

```
<html><body>
<form method="POST" action="someplace/foo.cgi">
<b>Registering form</b></b>
<br>Name: <input type="text" name="Name" value="" />
<br>E-mail: <input type="text" size="10" />
<input type="checkbox" name="c" value="send">Send me mail.
<br><input type="submit" value="Submit"/>
</form>
</body></html>

Registering form
Name: <input type="text" name="Name" value="" />
E-mail: <input type="text" size="10" />
<input type="checkbox" name="c" value="send">Send me mail.
<input type="submit" value="Submit"/>

Registering form
Name: _____
E-mail: _____ Send me mail.
_____

Registering form
Name: _____
E-mail: _____  Send me mail.
Submit
```

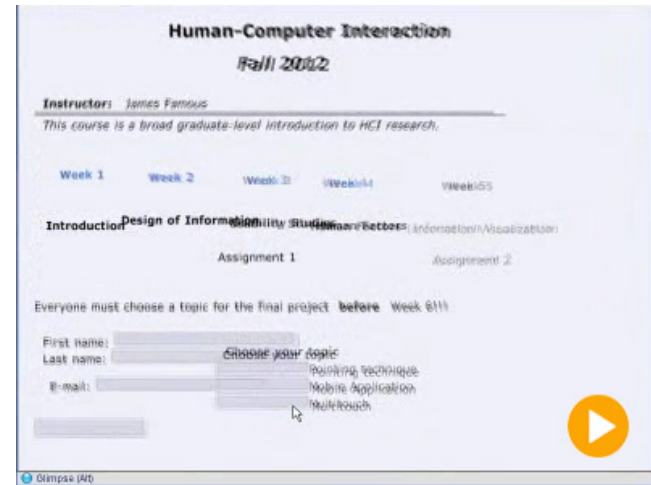


Figure 10. Top: The Glimpse authors use blurred versions of successive frames to convey an animation effect of html markup to a rendered document [6]. Bottom: An animated figure better conveys the animation.

Visualizing How an Algorithm Works

Animations can also be useful to explain how an algorithm works. For example, Baecker's Sorting out Sorting article [3] uses a sequence of static frames from the associated video to illustrate how the quick

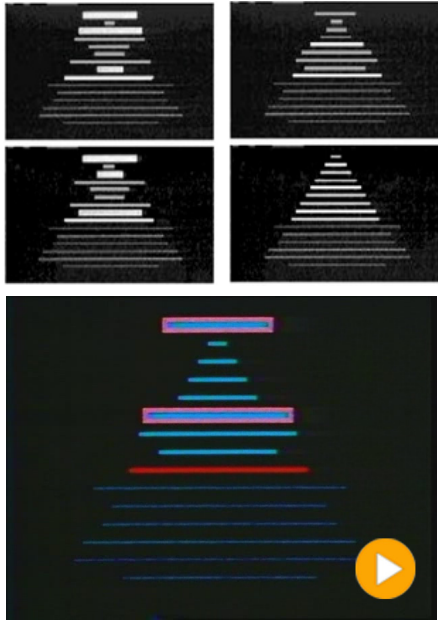


Figure 11: A sequence of diagrams to illustrate Quicksort from [3]. Bottom: An animated figure clearly illustrates the steps and internal states of Quicksort.

sort algorithm works. An animated figure taken from the actual video better portrays the dynamic sequences of the algorithm (Figure 12). Often, adding playback controls allows readers to understand and explore the sequence at the readers own pace.

Recommendations

We have reviewed how authors can create animated figures, and discussed several use cases where such figures could be beneficial inclusions within research articles. In this section, we propose a set of recommendations for what we believe to be best practices for embedding animated figures into scientific articles.

Duration

We recommend keeping videos short – just like traditional static figures, they should be used to communicate a single concise idea. The examples in this article are all under 20 seconds. We do not recommend embedding a video that describes an entire paper – such videos are still most appropriate as supplementary files.

File Size

Keeping the videos short also minimizes the file size of the final PDF. A larger PDF file may be downloaded less often, and may cause difficulties for readers (or reviewers). With today's typical download speeds, we would suggest a final PDF size of no greater than 20MB.

Audio

We would strongly recommend against using any audio, which could be very distracting to readers of the article. Animations should only include audio if the audio is critical, and such figures should use manual playback.

Number of Videos

When writing our own Draco paper, we tested a version of the PDF where almost all figures were animated (since animation was the topic of our paper). However, it seemed overwhelming and distracting to have numerous independent animations in the paper. As such, we elected to only include a single animated figure as the banner image on the first page of our paper. We would suggest limiting the number of animated figures used within a research paper, and only using them when it will be significantly beneficial to the reader in understanding the accompanying text.

Discussion

While paper-based media is still prevalent in our society, we do seem to be (slowly) transitioning towards electronic based media consumption. The prevalence of tablets and eBook readers has accelerated this transition. Obviously, the capabilities of these technologies extend beyond static text and images. Given that the majority of consumers of research articles do have access to modern PDF viewers, we believe it is perfectly reasonable to exploit their capabilities. As such, we are in favour of using animated figures in place of static images, but only in situations where it will significantly benefit a reader in understanding the accompanying text of the paper. Furthermore, the static or printed version of the paper should remain fully comprehensible even if animated figures are deactivated (see *Step 3* of our detailed instructions).

Caveats

Referring to this article does not in any way give an author permission to use animated figures for any individual conference or journal. That decision is

ultimately made by the conference organizers and associated publishers. However, we do encourage any publisher or conference organizer to allow this practice.

Furthermore, even if a conference or publisher allows it, there is a risk of including the animation in a PDF submitted for review. Reviewers may feel strongly against their use, even if it is allowed by the venue. For example, a colleague of ours knew someone who had a paper rejected because they tried embedding an interactive object within the submitted PDF.

We did extensive testing before submitting our animated PDF. If the workflow we have described above is used, the animation will work fine for common PDF readers (e.g., Adobe Reader). For readers where the animations are not supported, the static image is properly displayed instead. We did not encounter any problem, such as rendering errors or crashes. However, we can in no way guarantee the robustness of the outlined process.

To take precaution with our submission, we also included the static version of our PDF, as a supplementary file, in case any reviewers encountered difficulties. We also included a footnote with the animated figure:

"Figure 1 has been added to the PDF as a looping flash animation. If you experience any difficulties, please see our static version of this PDF or try a different PDF viewer."

We did not encounter any problems with our submission during the review or publication process. As far as we know, no one raised any concerns about the format of our submission.

Instructions and Regulations

As of today, most conferences and journals, including the ACM CHI conference, have no published policy on the use of embedded animations within submitted articles. However, there are existing research venues that have started to encourage the embedding of interactive content within PDFs. Examples include *The Journal of Neuroscience*² and *IEEE VIS 2014*³. Some research papers also argue for the use of multimedia content, including video and interactive 3D models [19]. *The Journal of Neuroscience* provides particularly good advice on when interactive media should be embedded into PDF files¹:

The Journal of Neuroscience will publish multimedia and 3D models embedded in the HTML and PDF versions of articles. Essential multimedia and models will be displayed in line with the article text, as is done for figures. Authors should be aware that multimedia and 3D models will not be available to readers who only access the printed version.

Authors should not use multimedia and 3D models simply to enliven or embellish their article. Because they substantially increase file sizes and are not available to all readers, multimedia and 3D models will be accepted only when they are needed to display findings that 1) are essential to defend the articles conclusions and 2) could not be presented adequately in the text, a table, or a figure.

We stress the importance of such official instructions as a reference for both authors and reviewers, and hope these types of guidelines will soon be adopted by other research venues, to encourage the appropriate use of

² http://www.jneurosci.org/site/misc/ifa_illustrations.xhtml

³ <http://ieevis.org/year/2014/info/call-participation/paper-submission-guidelines>

interactive content, in particular, animated figures, within submitted and published research papers.

Reliance on Commercial Software

One current limitation of animated figures is the reliance on commercial software for the production pipeline which we have described. This process requires several commercial applications, including Adobe Flash, Adobe Acrobat Pro, and Camtasia Studio. Future work should explore open-source applications that are able to similarly embed animated figures within PDF files. The media9 LaTeX pack is one possibility⁴.

In terms of viewing animated figures, it should also be noted that most, but not all PDF viewers are able to display animated figures. The *swf* capabilities are part of the published PDF ISO standard (ISO 32000 Extension Level 3), but some viewers still do not support playback. However, common and free PDF readers do support playback, such as Adobe Reader, Internet Explorer, and Safari.

Why PDFs?

The above point raises questions regarding the PDFs proprietary format itself as being the appropriate format for publishing. In subsequent discussions, reviewers advocated for the use of new tools and alternative paper formats. In particular HTML 5, offers responsiveness, accessibility, and can support dynamic and interactive content. Mark McGill (one of our reviewers) created a video of what such an HTML5 paper might look like, in reaction to our article⁵. We stress that while we provide concrete instructions on

how to create animated figures to integrate within a PDF, our intent is *not* to advocate for PDF file format as the immutable reference format for the future of academic publishing.

Accessibility

Digital accessibility has become an important topic in academic publishing. With the use of animated figures, authors should consider the impact on accessibility. For example, adequate alternative text should be supplied for any animated figure that is used.

Beyond Passive Reading - Interactive Figures

Embedding animated contents in scientific articles is a step towards more active reading experience in digital media. However, a truly dynamic representation of scientific knowledge would call for *interactive figures* within academic articles, providing a more active reading experience. Interactive figures invite exploration, allowing users to interact and change conditions and see consequences immediately. In academic papers, interactive diagrams can be beneficial in many cases, such as navigating a 3D model, exploring interactive statistical data charts, and illustrating how a dynamic software or hardware system works. This could also include embedded videos, which unlike animated figures, would give readers full interactive navigation controls.

Recently, Bret Victor redesigned Watts and Strogatz's seminal Nature paper on network theory [17] with a sequence of interactive illustrations (in HTML) coupled with captions. The steps of the algorithm were broken down into small enough chunks for linearity and exhaustivity. It allows the reader to see the intermediate data, states, and progression of the

⁴ <http://www.ctan.org/pkg/media9>

⁵ <https://www.youtube.com/watch?v=oka2XiMELyU>

algorithm over the steps with a slider. While gaining increasing popularity among journalists, artists, educators, and storytellers, such interactive diagrams are still underused in academic publishing.

Conclusion

We have described the steps used to create and embed *animated figures* within PDF documents. We have also outlined a set of use cases where animated figures could be beneficial, and discussed recommendations and caveats surrounding their use. While we discuss the use of dynamic elements supported by current technology, we hope this work will elicit broader debate and discussion amongst the community of researchers and publishers about the future of dynamic scientific publication formats.

Appendix

Please see our online appendix for detailed instructions, tutorial videos, and sample files:

<http://www.autodeskresearch.com/publications/animatedfigures>

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