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ROUNDTABLE 5: ANIMATING VICTORIAN SCIENCE

Victorian Science in Two and a Half Dimensions: Using 3D Software to Explore 19C Images

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Abstract

Animator Sydney Padua's interaction with 19th-century science includes an obsession with Charles Babbage, Ada Lovelace, and the Analytical Engine that led to some of the first visualisations and animations of the machine. Most recently she teamed up with the Constructing Scientific Communities project, and their work on Science Gossip, animating illustrations from the 19th-century nature periodicals into shareable gifs. In this paper she shares some of her inspirations and processes for making creative projects from historical archives.

Keywords: Analytical Engine; animation

This is a brief description of the genesis and methodology of two projects I developed as a professional animator engaging with subjects in Victorian science. The first is a short animation created to explain the operations of Charles Babbage's Analytical Engine, an unrealised design for a computer from the 1840s. The second is a set of small clips for the Constructing Scientific Communities project, animating illustrations from digitised scans of 19th-century nature periodicals.

Professionally, I am what is known as a "creature animator": I specialise in creating the movements of photorealistic animals and monsters for visual-effects films, from giant scorpions in *Clash of the Titans* to singing lions in the recent *Mufasa: The Lion King.* Our task as visual effects animators is to create moving images of impossible creatures, while mimicking real-world animals convincingly enough to blend in with live footage and fool the eye of the audience. These two projects gave me an opportunity to bring my animator's toolset to an area that had long fascinated me, scientific illustration, and in particular that of the Victorian era.

The 19th century was a great age of beautiful machinery, mass-produced images, and an intense public interest in a science which was still accessible to the layperson without too much specialised training. It produced a wealth of scientific illustration, much of it now available in digitised form. Both projects make use of this material in different ways, and were attempts to bring to life—to "animate"—some potential lying dormant in this historical material.

Animation itself has its genesis as a technology in the optical experiments of the 19th century, as my fellow-panellists explore. To 'animate' has a number of meanings.[1] Most literally, to "animate" is to create an illusion of movement by frame-by-frame juxtaposition and manipulation of still images. "Animate" can also mean "possessing life," as in an "animate" vs "inanimate" object; the zoetrope, one of the first animation-machines, means literally "life-turning." To "animate" again can mean to imbue with spirit or emotional energy, as a person might be described as "animated." Creating these three illusions—the illusion of movement, the illusion of life, and the illusion of thinking and emotion—is the craft of the animator.

1. Visualisations of Babbage's Analytical Engine

The first project is an animated short film (a work-in-progress at the time of writing, viewable at https://youtu.be/gODpK9dTEWc), expanding on visualisations of Charles Babbage's Analytical Engine that I had undertaken to create as part of a graphic novel published with Parthenon Books in 2015, *The Thrilling Adventures of Lovelace and Babbage.* The book was based on a web-comic I had been writing and drawing between 2009 and 2015, set in an alternate universe in which actual 19th-century mathematician Charles Babbage and his friend and collaborator Ada Lovelace successfully build a steam-powered computer, the Analytical Engine, and use it to fight crime.[2] The Analytical Engine was a design for a computer-like calculating machine conceived by Babbage between the 1830s and 1860s, but never built—one of the most famous what-ifs in the history of science.

The book's structure, like that of the webcomic, was a fact-and-fiction collage of documents, facts, and anecdotes about the historical personalities and science, with fantastical adventure comics set in the alternate universe. As the play between reality and imagination was central to the concept, it was clear that the book would have to include diagrams of the machine at the heart of the story, and a description of how it would have worked.

My own understanding of the Analytical Engine had been, even well into the process of writing the book, fairly vague. I do not have a background in computer science, and like many people, I viewed the device I spent most of my days on as a mysterious and necessary evil. As the usual sources of Wikipedia and popular science books only described the machine in the most general terms, I turned to the academic literature to find images that I hoped I could crib from, to produce a majestic drawing of the completed machine. I soon came across the invaluable work of the late Alan Bromley. Without his many articles on Babbage's work in the *Annals of the History of Computing*, my task would have been absolutely impossible. Bromley's descriptions, however, were almost entirely in the form of text; their value was in explaining clearly what Babbage's mechanisms were intended to do.[3] To my great surprise, I found that no full visualisation of the Analytical Engine had been published or even, to the best of my knowledge, seriously attempted. Babbage himself had left no images for the entire machine. He did leave many diagrams and sketches of individual mechanisms in many

[1] The definition of animation is a somewhat contentious subject. The 'frame-by-frame technique' definition is used most prominently by the Academy of Motion Pictures to determine what qualifies for the animation categories of the Academy Awards (available at: https://www.oscars.org/sites/oscars/files/2024-04/97_ani_feature_rules.pdf Accessed Nov 01 2025). For more academic discussions on what constitutes "animation", see, for example, Martinez 2015 and Wells 2011.

[2] The online comic was a personal project with no particular aim, and has I am afraid not been touched in many years; but the website in a somewhat dilapidated state can still be found at 2dgoggles.com.

[3] In particular: Babbage 1982, 196–217, 1987, 113–36.

Figure 1. Queen Victoria confronts the Analytical Engine, from *The Thrilling Adventures of Lovelace and Babbage*, Pantheon Books, 2015.

iterations, as well as flow charts of the machine's operations, often written only in his "mechanical language," an abstract shorthand.[4] Although I had a clearer understanding of the Engine, I still could not "grasp" it, or answer for myself or others the basic questions "what did it look like?" and "how did it work? (see Figure 1)"

I turned to the tool with which I was most familiar, Alias-Wavefront Maya, the 3D animation program used by most visual effects studios and in which I have spent most of my working life as an animator. *Mufasa: The Lion King*, for example, on which I was a lead animator, was entirely animated in Maya. Maya provides a 3D environment in which virtual objects can be modelled, moved around, keyframed, and rendered.

When speaking about my Engine visualisations to computer scientists and engineers, I often have to explain that what they are looking at is an *animation*, not a *simulation*—an *illusion* of engineering, a façade rather than architecture. Maya is owned by the same company, Autodesk, that makes AutoCAD, the industry-standard engineering software, but it is quite different in emphasis. Maya does not, in any useful way, run physics simulations or calculate how objects would react to each other—animation in Maya is created frame-by-frame by hand, much like a stop-motion film. This does make it an extremely useful tool for quickly making simple virtual objects and playing around with them. My method for understanding

[4] Some of the diagrams I used, together with Babbage's pamphlet on his mechanical language, are collected in his son Herschel Babbage's *Babbage's Calculating Engines: Being a Collection of Papers Relating to them; their History and Construction.* A new edition was issued by Cambridge University Press in 2010.

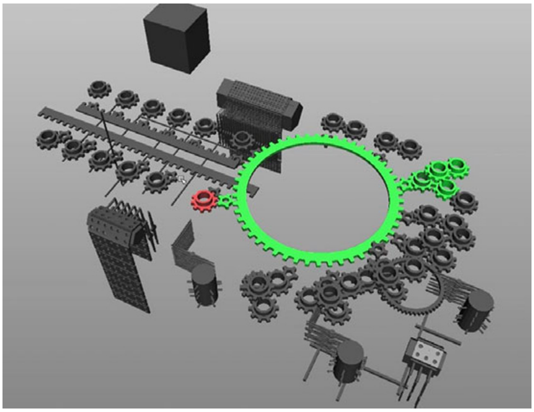


Figure 2. Analytical Engine blockout, screenshot from Maya. *Source:* Built by the author.

the Engine was to bring scans of diagrams into Maya, build virtual geometric objects from them, and then move them around to puzzle out how they would interact in space.

Through this laborious method, I eventually managed to build a coherent 3D structure of the principal mechanisms and their connections to each other, as well as animating them as they would have been intended to operate—cog A, driving rack B, which drives cog C, and so on (see Figure 2). As an animator, I found this process unexpectedly intuitive. If animating, for example, a lion jumping, the animator feels out how the force transmits through the joints of each toe, up the leg, and into the shoulder and spine, the logic of the anatomy expressing itself in motion. It was challenging but within my skillset to understand the Engine as a similarly anatomical animal, with linked gears and levers acting much as muscles and joints would do.

I believe this is the great advantage of the Analytical Engine for communicating computer science principles to the public. I would certainly have found an electronic machine, with invisible forces travelling instantaneously inside boxes and wires, far more difficult to understand, as well as infinitely less engaging. As a mechanical computer, every function of the Engine, from memory to addition, is a comprehensible physical action. An "instruction" to a computer might be a murky concept, but when it is simply a hole made in a card that allows a lever to connect with another lever, it becomes suddenly illuminated. A computer that moves like an animal, an intricate but comprehensible creature of connecting joints, can be intuitively grasped in a way that the light-speed, atomic-scale operations of a modern computer cannot.

By rendering and drawing over my 3D models, I was finally able to produce the centrepiece diagram I was aiming for, as well as a fairly coherent description of how it would have operated—something I would never have been able to do without being able to see and animate them in Maya. Although it has been 10 years since *The Thrilling Adventures of Lovelace and* Babbage was published, I still have frequent requests from academics in computer science to make use of my visualisation, particularly for public-engagement talks for general audiences. I realised, however, that many people still found the explanation of the operations of the Engine extremely difficult to follow—things that move and change in relationship are simply very difficult to express in a still image. Babbage himself lamented "the difficulty of retaining in the mind all the cotemporaneous and successive movements of

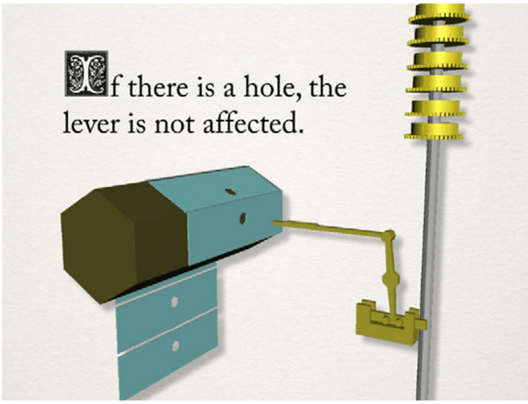


Figure 3. Clip from work-in-progress Analytical Engine Film. The initials and text font are digitised from the 1847 Elements of Euclid, kindly provided by Nicholas Rougeux's Byrne's Euclid project, at https://www.c82.net/euclid/. *Source:* Sydney Padua 2025.

a complicated machine."[5] In an attempt to bring greater clarity, after the book came out, I recorded a 12-minute screen recording talking my way around the original models I'd constructed for my own understanding inside Maya.[6] Despite the very unbeautiful greyscale models and hasty voice-over, it currently has 57,000 views on YouTube; a video making extensive use of the same animations by the YouTube channel Computerphilestands at nearly a quarter of a million views.[7] Clearly, there is demand for a clear visual explanation of the Analytical Engine, either for formal educational purposes, or for simple curiosity.

I am currently in the process of producing a more attractive and efficient video explainer of the Analytical Engine (see Figure 3), a draft version of which was shown at the BSLS conference in Lancaster in 2025.

2. Constructing scientific communities animations

The second project was a series of short animation clips I created as Artist-in-Virtual-Residence for the Constructing Scientific Communities project (https://conscicom.web.ox.ac.uk/home) in 2016, involving the digitised archives of the Biodiversity Heritage Library. The public was invited to contribute by identifying and tagging illustrations and diagrams from a set of 19th-century natural history periodicals, which themselves had been the work of dedicated amateurs. Over 160,000 images were identified and tagged, including many beautiful animal engravings. My brief was an open-ended one, to celebrate and raise awareness for the project by doing what I wished with this vast set of scientific illustrations that were given into the public domain.

At that time, I was wrapping up work on the 2016 *Jungle Book* adaptation for Disney. As with nearly all my professional work for the last several years, my task had been to create photorealistic animals to blend into live-action footage. "Creature animation" like this involves closely observing footage of real animals to reproduce their actions, and every department involved, from modelling to animation to muscle and fur simulation, must

[5] Babbage 1826, 1.
[6] Sydney Padua 2015.
[7] Computerphile 2016.

meticulously study and anatomise the animal—much like a scientific illustration. I also found a kinship with the (largely anonymous, as film animators also generally are) 19th-century artists' laborious process of engraving images line by line, which had a resonance with my own frame-by-frame craft of animation. I wished to honour the labours of the artists who had created the original illustrations, and the long-dead animals they had frozen to the page, by adding a dimension of movement.

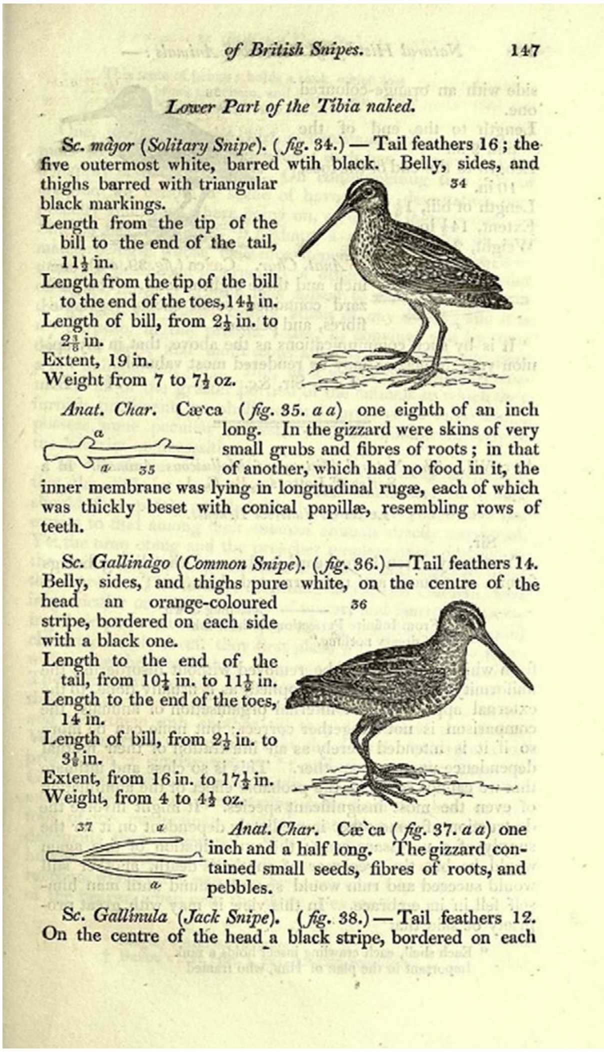
"Animal," of course, shares the same root as "animate"—"anima", meaning life, breath, or spirit—and the movements of animals have a particular ability to catch the attention. The actions of muscles and joints in a nervous system directed by an animal brain have a very specific profile, one which is recognised at a subconscious level by our visual system.[8] Much of the training of the animator involves learning how to create an illusion of motion that is specifically biological. Mimicking this movement profile successfully is what creates the illusion that an animated character is alive, even as the audience knows that it is not. If not done successfully, the image may appear to move, but it will not have the same "magical" effect, much as a poorly done magic trick will not give the audience the same thrill as a successful one. My goal was to create a moment of delight when the engraving "came to life."

I had also been looking for an opportunity to experiment with what is informally known as "2.5D": animation that combines 3D graphics with drawing, cut-out planes, and other 2D techniques. As an "industry" animator, particularly in VFX, which prizes realistic illusions above individual style, I did not usually have much opportunity professionally for this kind of exploration.

I selected some images that felt suitable for animation—an animal that could be cleanly separated from a background, in a pose in which I felt some sort of incipient motion (see Figure 4 for example). I cut them out in Photoshop into individual parts (i.e., upper leg, lower leg, foot, toes, etc.), then jointed the parts together using Maya's rigging tools (Figure 5), which allowed me to move and animate them freely. All 3D animated films use the same basic technique of jointing a geometry, although this is usually done on 3D models rather than 2D planes. As with any cut-out animation, I was restricted to movement on a single plane (Figure 6). This helped support the illusion of an inky animal moving around inside its paper habitat, but it was very restrictive in terms of the action of the animal's limbs. If I were to approach a similar project today, I would probably use a different technique that would allow me more control over the engraved lines themselves. Newer software, such as Moho or Spine, can convert lines to a vector format and animate them in clusters, which would allow me to create an illusion of a drawing come to life with more subtlety than the cut-out planes I was restricted to with Maya.[9]

When deciding which actions to animate, I wanted to have the creature either enter, or leave, the page, either creating or filling a blank. I felt it would highlight the ephemeral, fluid, fragile nature of a living creature in contrast to the rigid lines of text and labels of scientific names that attempted to "pin" the animal to the page. I kept the animations short and small enough to share easily on social media as individual moments—ideally as GIF files, which can be shared and embedded in social media. I completed four of these animations (Figures 7–10) which were widely shared on social media. Nearly 3000 visitors have visited

[8] Puce and Perrett 2003.
[9] Lost Marble 2025.



of *British Snipes.* 147

Lower Part of the Tibia naked.

Sc. major (*Solitary Snipe*). (*fig.* 34.) — Tail feathers 16; the five outermost white, barred wtih black. Belly, sides, and thighs barred with triangular black markings.

34

Length from the tip of the bill to the end of the tail, $11\frac{1}{2}$ in.
Length from the tip of the bill to the end of the toes, $14\frac{1}{2}$ in.
Length of bill, from $2\frac{1}{2}$ in. to $2\frac{3}{8}$ in.
Extent, 19 in.
Weight from 7 to $7\frac{1}{2}$ oz.

Anat. Char. Cæ'ca (*fig.* 35. *a a*) one eighth of an inch long. In the gizzard were skins of very small grubs and fibres of roots; in that of another, which had no food in it, the inner membrane was lying in longitudinal rugæ, each of which was thickly beset with conical papillæ, resembling rows of teeth.

a *a* 35

Sc. Gallinago (*Common Snipe*). (*fig.* 36.) —Tail feathers 14. Belly, sides, and thighs pure white, on the centre of the head an orange-coloured stripe, bordered on each side with a black one.

36

Length to the end of the tail, from $10\frac{1}{4}$ in. to $11\frac{1}{2}$ in.
Length to the end of the toes, 14 in.
Length of bill, from $2\frac{1}{2}$ in. to $3\frac{1}{8}$ in.
Extent, from 16 in. to $17\frac{1}{2}$ in.
Weight, from 4 to $4\frac{1}{2}$ oz.

37 *a* *a*

Anat. Char. Cæ'ca (*fig.* 37. *a a*) one inch and a half long. The gizzard contained small seeds, fibres of roots, and pebbles.

Sc. Gallinula (*Jack Snipe*). (*fig.* 38.) — Tail feathers 12. On the centre of the head a black stripe, bordered on each

Figure 4. The original scanned page. *Source:* Image from Gossip 2023a.

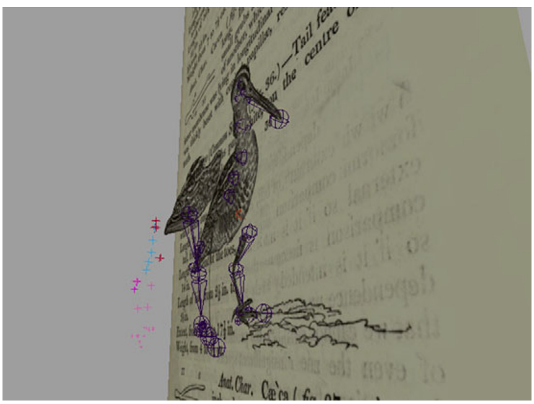
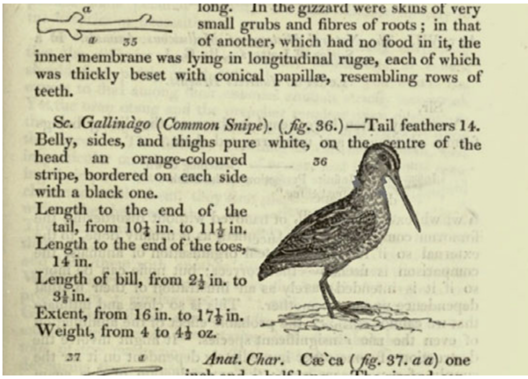


Figure 5. Maya screenshot of the jointed cut-out planes used to animate the snipe.



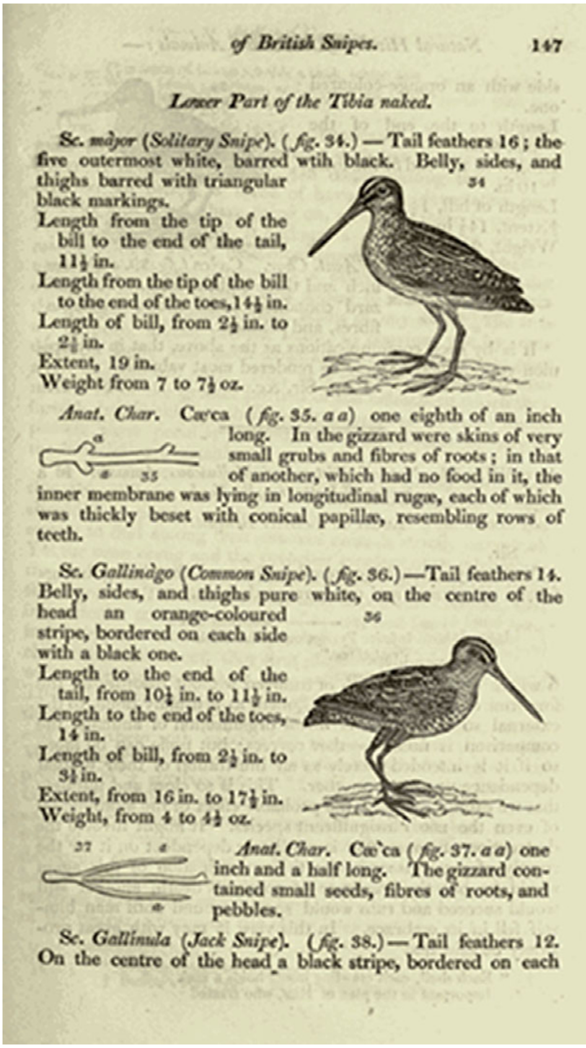
long. In the gizzard were skins of very small grubs and fibres of roots; in that of another, which had no food in it, the inner membrane was lying in longitudinal rugæ, each of which was thickly beset with conical papillæ, resembling rows of teeth.

Sc. Gallinàgo (*Common Snipe*). (*fig.* 36.)—Tail feathers 14. Belly, sides, and thighs pure white, on the centre of the head an orange-coloured stripe, bordered on each side with a black one.

Length to the end of the tail, from 10¼ in. to 11½ in.
Length to the end of the toes, 14 in.
Length of bill, from 2½ in. to 3½ in.
Extent, from 16 in. to 17½ in.
Weight, from 4 to 4½ oz.

Anat. Char. Cæ'ca (*fig.* 37. *a a*) one

Figure 6. The same frame from the camera view. The camera is set to a 300 mm lens, making the image appear completely flat.



of British Snipes. 147

Lower Part of the Tibia naked.

Sc. màjor (*Solitary Snipe*). (*fig.* 34.) — Tail feathers 16; the five outermost white, barred wtih black. Belly, sides, and thighs barred with triangular black markings.

Length from the tip of the bill to the end of the tail, 11½ in.
Length from the tip of the bill to the end of the toes, 14½ in.
Length of bill, from 2½ in. to 2¾ in.
Extent, 19 in.
Weight from 7 to 7½ oz.

Anat. Char. Cæ'ca (*fig.* 35. *a a*) one eighth of an inch long. In the gizzard were skins of very small grubs and fibres of roots; in that of another, which had no food in it, the inner membrane was lying in longitudinal rugæ, each of which was thickly beset with conical papillæ, resembling rows of teeth.

Sc. Gallinàgo (*Common Snipe*). (*fig.* 36.)—Tail feathers 14. Belly, sides, and thighs pure white, on the centre of the head an orange-coloured stripe, bordered on each side with a black one.

Length to the end of the tail, from 10¼ in. to 11½ in.
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Anat. Char. Cæ'ca (*fig.* 37. *a a*) one inch and a half long. The gizzard contained small seeds, fibres of roots, and pebbles.

Sc. Gallinula (*Jack Snipe*). (*fig.* 38.) — Tail feathers 12. On the centre of the head a black stripe, bordered on each

Figure 7. Snipe animation by Sydney Padua. *Source:* Original image from Gossip 2023a.

Figure 8. Butterflies animation, Sydney Padua. *Source:* Original image from Gossip 2023b.

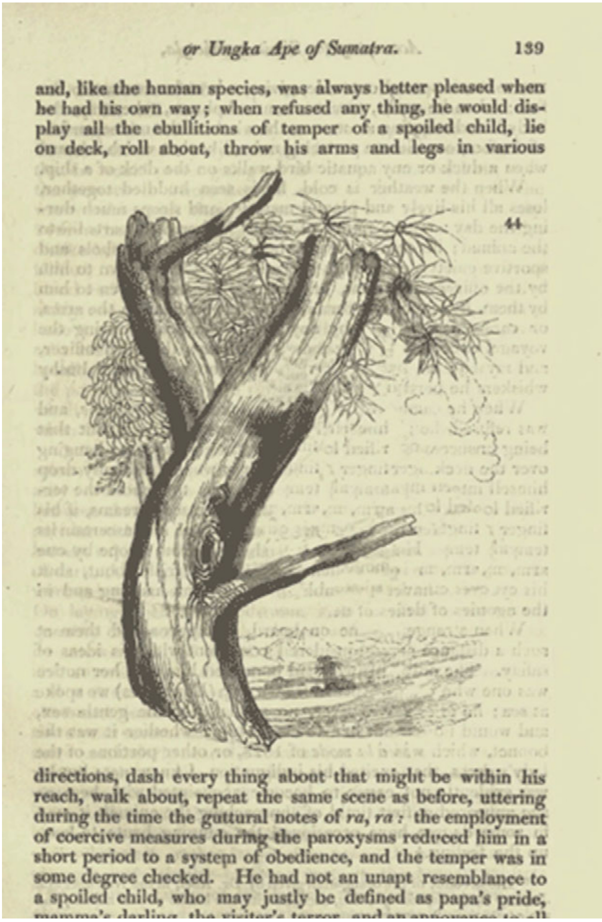
the Constructing Scientific Communities site from my own website's page on the project, furthering the public engagement goals of the project.[10]

3. Useful and Useless Animation

These two projects combine archival 19th century diagrams with modern animation tools, to spark a connection between contemporary audiences and neglected historical materials. All these images, static and animated– the Babbage diagrams, the Engine visualisations, the beautiful bird engravings and their moving versions—were created to connect with an audience that might find a visualisation more compelling or clear than a verbal explanation. The analytical engine project falls under a framework termed by Malcom Cook 'useful animation: animation as a "practical and conceptual tool in professional fields,"[11] as distinct from animation's more common associations with art and entertainment. If the Analytical Engine project is "useful animation", the Science Gossip clips, inversely, take a "useful"

[10] Ox.ac.uk. 2025; Sydneypadua.com. 2025.

[11] Cook et al. 2023.


or Ungka Ape of Sumatra. 139

and, like the human species, was always better pleased when he had his own way; when refused any thing, he would display all the ebullitions of temper of a spoiled child, lie on deck, roll about, throw his arms and legs in various

directions, dash every thing about that might be within his reach, walk about, repeat the same scene as before, uttering during the time the guttural notes of *ra, ra*: the employment of coercive measures during the paroxysms reduced him in a short period to a system of obedience, and the temper was in some degree checked. He had not an unapt resemblance to a spoiled child, who may justly be defined as papa's pride,

Figure 9. Gibbon animation, Sydney Padua. *Source:* Original image from Gossip 2023c.

explanatory image and showcase animation in its more familiar function: simply to delight the eye with the inert coming impossibly to life. In a sense this may be seen as a subversion of the "usefulness" of the image as scientific illustration, undermining its serious function with the playfulness of illusion. Animation can combine usefulness and ornament, wonder with information, explanation with entertainment, creating an accessible bridge to audiences of all kinds, particularly those who might find abstract or historical material alienating.

I began this piece with some of the many definitions of "animation." I can add that in many French-speaking countries, an "animateur" is a professional role as a host, explainer, and facilitator of cultural activities—someone who "enlivens." In a screen-based, digitised, social media world where short moving clips are king, the frame-by-frame illusionist type of animator can play a similar role.

Sydney Padua is a graphic novelist, animator, and academic. Her animation work includes hand-drawn and computer-generated; independent and mass-media works; most recently, she was an Animation Lead on *Mufasa: The Lion King*. Her cult webcomic, *The Thrilling Adventures of Lovelace and Babbage*, became a bestselling graphic novel, nominated for two Eisner Awards, and winner of the British Society for the History of Mathematics Neumann Prize.

Figure 10. Toad animation, Sydney Padua. *Source:* Original image from Gossip 2023d.

Her animated reconstructions of the proto-computer, the Analytical Engine, were some of the first visualisations ever done of that extraordinary machine. She is currently a Senior Lecturer in Animation at Buckinghamshire New University.

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