Time machines

Stephen Boyd Davis, Lansdown Centre for Electronic Arts, Middlesex University
s.boyd-davis@mdx.ac.uk

Abstract

The paper is concerned with the use of computers to represent historical time visually, typically as 'timelines'. Research into the sophisticated practice and theory of early modern paper timelines in the eighteenth century reveals the weakness of current practice, especially on the Web. Behind the work of the early pioneers lay a vision of mechanising knowledge. At that time, this proved a productive metaphor, but in our own time the mechanistic properties of computers have tended to encourage an approach to visualising history that excludes all but the crudest aspects. Solutions are needed which use computing in ways that do justice to the demands of historiography.

Information technology mechanises thought, a move almost guaranteed to invoke anxieties about the death of art history – at least outside the CHArt community. What could be worse than to introduce into a subtle, humanistic, richly interpretive domain, devices, systems and approaches that are reminiscent of machinery? This paper argues that mechanical approaches need not preclude subtlety, richness and interpretive power. Its focus is on the visual representation of historical time and, in particular, the design of timelines. It may seem strange to devote a paper to such a trivial topic, but the perception of triviality is part of the problem. Timelines, or the more general class of *chronographics* to which they belong, deserve serious study, both historically as significant artefacts, and as devices to enhance historical understanding. The sophisticated thinking of the early chronographers – which they found hard to turn into practice using paper and print – can be usefully brought together with the capabilities of digital information technology. However, present practice tends to the simplistic and gives computing a bad name.

Chronology, chronography and the timeline

It may be that the whole idea of *dates* as a significant aspect of history is questionable. However, we benefit from the remarkable achievements of early chronologers who provided the essential scaffolding of historical time now taken for granted. Chronology was once a serious study in its own right. Feeney records many instances from classical times,[1] while Grafton has traced extensive Renaissance practice, in particular the work of Scaliger.[2] In the 18th century, while 'history' had connotations of narrative and story (the French *histoire* still does), chronology provided rigour. What chronology added to history, various authors argued, was meaning, vividness, memorability, an evidential basis, and a unifying framework. Locke considered chronology necessary to give history form and meaning.[3]

Unfortunately, chronographics have tended to escape serious study: rare exceptions include Twyman's historical work at Reading[4] and some interesting digital prototypes at the University of Maryland.[5] However, there are signs of change: an exemplary pictorial and historical survey of chronographics has recently been published by Rosenberg and Grafton,[6] while Rosenberg[7] is essential reading on the chronographics of Joseph Priestley, a key figure in the present paper. As this paper will show, Priestley's work lies at a critical moment in the mid 18th century when the principles of mechanisation had a productive effect on thinking about the visualisation of history.

Traditionally, chronology was presented in the form of lists and tables – even now, the majority of documents on the Web called timelines are merely chronological lists. But in a pioneering example, Helvicus (1581-1617) attempted to use visual space to enhance the reader's grasp of temporal intervals by using an equal number of pages for every hundred years, rather than packing all the data into the minimum space: *Praecipuum, quod in hoc Systemate spectavi, est annorum a Mundo condito ad nostra tempora usque per aequalia Centenariorum et Decadum spacia distributio, ob* *eximium usum, qui inde resultat* (The main goal I aimed at in this treatment is an equal distribution of years between the creation and our time in intervals of 100 years and 10 years, because it is so useful). [8] He insisted on the importance of the structural relations between events: 'the Synchronism of Famous Men, renowned either for their Vertues or their Villanies, doth very much promote a sound knowledge in History.'[9] More than a century later, historic time was mapped truly arithmetically to space by doctor, botanist and philologist Jacques Barbeu-Dubourg (1709–1779), who in Paris in 1753 created a chart 16.5 metres long plotting all history from the Creation to his own time on a uniform timescale.[10] It is accompanied in the author's explanatory leaflet by a significant appearance of *mechanism* as a desirable model.

Mechanising cognition

Barbeu-Dubourg acknowledges that he has been inspired by Geography, with its maps, globes and other appealing visual aids: he now plans to make Chronology equally beguiling.

> All have evinced some surprise to see Chronology metamorphosed into Chronography, to see that a science of memory so cold, so sterile, so insipid, may become a science entertaining, and so to speak *mechanised* [pour ainsi dire *méchanique*], which speaks to the eyes and to the mind, […] where memorable events so strike the senses, organise themselves so effortlessly in the memory, and are imprinted there so strongly, that we learn almost *automatically* [on s'instruit presque *machinalement*], hardly needing to think what we do.
>
> (Barbeu-Dubourg 1753: 8. Emphasis added)[11]

Machinalement like all mechanical terms was an ambivalent concept. On the one hand we find it said of natural movements in which the will plays no role (*se dit des mouvemens naturels où la volonté n'a point de part*)[12]: someone may reply *machinalement* when they have not heard what was said. In this context, thoughtless automatism is foremost. In English at the same time the word *mechanical* had a number of derogatory senses. It could deprecate materialist philosophies: 'to confound Temptation now with mere sadness of Spirit, and its dreadful effects with those of meer Mechanical Principles, is to talk like Aristotle, more than St. Paul.'[13] A character assassination of the 3rd Earl of Bute, critical of his encouraging scientific interests in the young George III, complains of his 'garnishing his knicknackatory with mechanical toys, baubles, and gimcracks.'[14] It frequently has an element of class condescension, especially where, as was traditional, the mechanical arts are contrasted with the liberal. Thus Defoe mocks a shoemaker-turned-highwayman who had 'an Inclination of laying aside his mechanical Employment, to translate himself into a Gentleman.'[15] Even someone as sympathetic to the practical as Franklin could write about '…The Arts, which are more or less liberal or mechanical, as they more or less partake of assistance from the operations of the mind,'[16] while elsewhere he regrets the 'mechanical sort of Enjoyment' experienced by 'People of low Education and mean Understandings.'[17] So much for the mechanical, apparently. But there is implied praise in Hume's remark that 'Another advantage of industry and of refinement in the mechanical arts is, that they commonly produce some refinements in the liberal arts: nor can the one be carried to perfection, without being accompany'd, in some degree, with the other.'[18] Hooke had said of Wren that 'since the time of Archimedes there scarce ever has met in one man, in so great a perfection, such a mechanical hand, and so philosophical a mind,'[19] while it was later said of Hooke himself that 'his mechanical inventions, of which the mathematical and philosophical world is abundantly convinced, are too numerous to repeat.'[20] The chronographics of Barbeu-Dubourg and Priestley discussed here coincide with the great *Encyclopédie* of Diderot and d'Alembert which, inspired by Bacon and Locke, aimed to treat the mechanical and liberal arts with equal respect.[21] Though Mayr[22] suggests a growing British aversion at this time to mechanical metaphors and models, a more nuanced impression emerges when the usage of the term is mapped to the motivations of the authors. For freethinkers, dissenters, proto-scientists and atheists 'mechanical' could be a term of admiration while for conservatives, especially religious ones, it was generally a term of abuse.

In Barbeu-Dubourg's argument, the claimed facility to perceive and to remember *presque machinalement,* effortlessly, is clearly a virtue. Perhaps the most striking aspect of mechanism here is the notion of cognitive automatism: what is seen is absorbed by the mind. This proves a touchstone of early visualisation, and such an idea of effortlessness through mechanism had its own history. Sawday notes how Leonardo shared a general view of machines as devices for overcoming the resistance of nature and getting something for nothing, until more sophisticated theories of work and energy showed that this was theoretically impossible.[23] Harkness remarks how the Elizabethans claimed cognitive benefits for the use of mechanical devices: John Blagrave promised that his instrument would lead the reader on a 'direct pathway (from the first step to the last) through the whole arts of astronomy, cosmography, geography, topography [and] navigation' with 'great and incredible speed, plainness, facility and pleasure.'[24] For anyone who endured the hyperbole around the educational benefits of multimedia in the 1980s and 90s, these claims will have modern echoes, particularly the notion of direct, effortless transfer of information to the brain (an idea enjoyably undermined at that time by McKendree, Reader and Hammond[25]). Barbeu-Dubourg is a paradigm of naivety: his *Petit Code de la Raison Humaine* political essay of 1789 is optimistic and simplistic even by the standards of the time (he lost his small fortune in attempting, out of idealism, to supply arms to the American revolution, competing unsuccessfully for the role with Beaumarchais, the author of the *Barber of Seville* and the *Marriage of Figaro*).[26]

But where Barbeu-Dubourg's explanation for his chart is naïve (or perhaps just a sales pitch), that of Joseph Priestley (1733–1804), theologian, dissenter, natural philosopher and radical, is subtle and thoughtful. The twenty-five page booklet describing his 1765 *Chart of Biography* contains about fifty substantive ideas. Not surprisingly his thoughts on the mechanical are also more nuanced than Barbeu-Dubourg's. At one point he explains that his Chart is 'one of the mechanical methods of facilitating the study of that science [ie. history].'[27] We are dealing here with a familiar notion of the mechanical that implies something physical and procedural, perhaps requiring little thought. But another use of the term is noteworthy. Priestley discusses how the timescale of his *Chart* (like Barbeu-Dubourg's) is linear, using equal space for equal time. He compares his own design favourably with the non-linear design of a recently imported French chart, almost certainly that of Barbeau de la Bruyère (1710-1781).[28] He clearly sees that the mechanical in visual perception is a quality which must be handled with care:

> the same scale is made use of through the whole of the chart of Biography [ie. Priestley's own], whereas several are used in that of History [ie. Barbeau de la Bruyère's]: the consequence of which is that, in comparing intervals of time in different parts of that chart, the imagination is necessarily imposed upon. Even the notice which is given of this change is not sufficient to correct the error of the imagination, which is *impressed mechanically by the view of the spaces*, as they are laid down in the chart…
>
> Priestley 1764: 8 (emphasis added)

In other words, something misleadingly designed, once perceived, will also be fixed in the memory. Here the potentially dangerous automatism of perception is highlighted. What is cognised mechanically cannot subsequently be undone by ratiocination. In our own time the visual is often presented as unambiguously beneficial: a graphical timeline is assumed to be more informative than a list of dates, however badly it is designed. Since that early remark by Priestley the potential of visualisation to be misleading has been little touched on, though a worthy heir of Priestley in this respect is the connoisseur of diagrams Edward Tufte[29] who repeatedly emphasises the misleading nature of much visual information.

Mechanical knowledge structures

While Barbeu-Dubourg seems in 1753 to have been the first to plot historical time arithmetically, in 1765 Priestley first represented duration using a printed line to represent each life[30]: 'They are the lines, in this case, which suggest the ideas, and this they do immediately, without the intervention of words.'[31] This eminently mechanical approach to representation takes Priestley some effort to explain, but he suggests that it works because of a natural mapping in thinking about time as though it were space: 'The very epithets which, in all languages, are given to quantities of time do both imply this method […] thus a longer or a shorter space of time may be most commodiously and advantageously represented by a longer or a shorter line.' The one is automatically mapped to the other: a certain lifetime produces a line of a corresponding length, as though drawn mechanically (Figure 1). The result has an intriguing resemblance to a piano-roll, which of course embodies a reverse relationship in which a representation drives a machine.

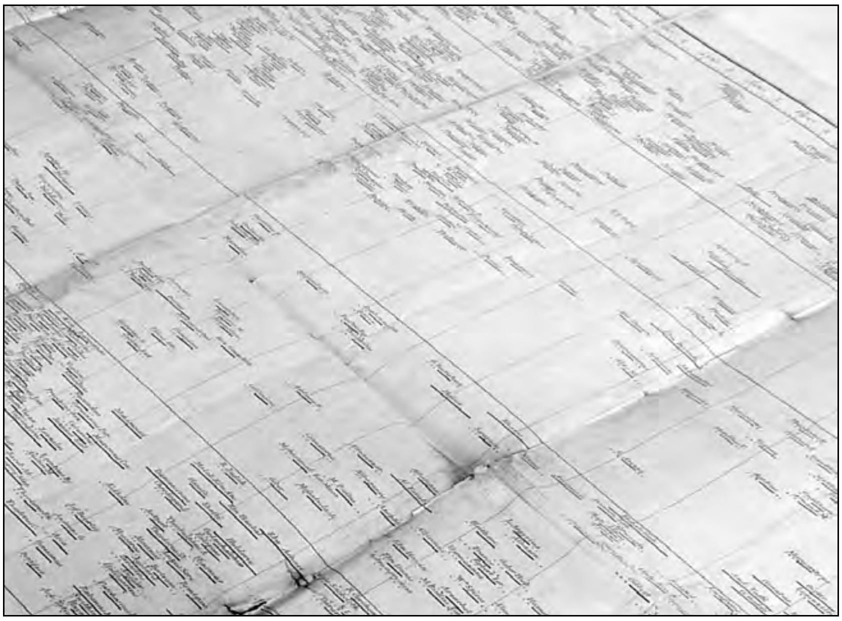

Figure 1 Joseph Priestley's 1765 *Chart of Biography* (detail). Clusters and periods with little data are clearly visible in this mechanical mapping of time to space. Reproduced with the permission of Chetham's Library, Manchester.

An important neglected work by Priestley is his 1777 *Harmony of the Evangelists in Greek* (and subsequently in 1780 in English). As so many had done before him (and continued to do afterwards), he grappled with the chronological difficulties of the four gospels in the New Testament. How to make one coherent history from four different accounts? Again he espouses an explicitly mechanical approach. His argument shares some of Barbeu-Dubourg's over-enthusiasm for rapid and automatic comprehension:

> I venture to say that, by the help of such a *mechanical* contrivance as this, a person of a very moderate capacity, or critical skill, will have an advantage over a person of the greatest genius and comprehension of mind without it. For, by this means, the things to be compared are brought under the eye at the same time...
>
> Priestley 1780: *xvii* (emphasis added)[32]

Figure 2 shows the result. The most striking feature is again the visual gaps, the empty spaces, at times resembling the famous empty page in *Tristram Shandy* by Priestley's older contemporary Sterne (1713-1768). He describes his method: 'If I should be thought to have succeeded in this work better than the generality of my predecessors, I shall attribute it chiefly to the *mechanical methods* I made use of' (p*xvi* original emphasis). He goes on to explain how he cut up two copies of the gospels and rearranged them. The physical, mechanical nature of the process was of help to him as well as to his readers: he was able to move the elements about as his ideas changed, before fixing them just prior to going to print (p*xvii*).


OF THE GOSPELS. 19

MATT. III.

11 I indeed baptize you with water unto repentance; but he that cometh after me is mightier than I, whoſe ſhoes I am not worthy to bear: he ſhall baptize you with the Holy Spirit, and *with* fire.

12 Whoſe winnowing ſhovel *is* in his hand, and he will thoroughly cleanſe his floor, and gather his wheat into the garner; but he will burn up the chaff with unquenchable fire.

LUKE III.

15 And as the people were in expectation, and all *men* muſed in their hearts of John, whether he were the Chriſt, or not;

16 John anſwered, ſaying unto them all, I indeed baptize you with water; but one mightier than I cometh, the latchet of whoſe ſhoes I am not worthy to unlooſe: he ſhall baptize you with the Holy Spirit, and with fire:

17 Whoſe winnowing ſhovel *is* in his hand, and he will throughly purge his floor, and will gather the wheat into his granary; but the chaff he will burn with fire unquenchable.

18 And many other things in *his* exhortation preached he unto the people.

MARK I.

7 And preached, *ſaying*, There cometh one mightier than I after me, the latchet of whoſe ſhoes I am not worthy to ſtoop down and untie.

8 I indeed have baptized you with water: but he ſhall baptize you with the Holy Spirit.

LUKE III.

21 Now when all the people were baptized, it came to paſs, that Jeſus alſo being baptized, and praying, the heaven was opened,

22 And the Holy Spirit deſcended in a bodily appearance, as a dove upon him, and a voice, came from heaven, which ſaid, Thou art my beloved Son; in thee I am well pleaſed.

MATT. III.

13 Then cometh Jeſus from Galilee to Jordan unto John, to be baptized of him.

14 But John forbade him, ſaying, I have need to be baptized of thee, and comeſt thou to me?

15 And Jeſus anſwering, ſaid unto him, Suffer *it to be ſo* now: for thus it becometh us to fulfil all righteouſneſs. Then he ſuffered him.

16 And Jeſus, when he was baptized, went up ſtraightway out of the wa-

MARK I.

9 And it came to paſs in thoſe days, that Jeſus came from Nazareth of Galilee, and was baptized of John in Jordan.

10 And ſtraightway coming up out of the water, he ſaw the heavens opened, and the Spirit as a dove deſcending upon him.

11 And there came a voice from heaven, *ſaying*, Thou art my beloved Son, in whom I am well pleaſed.

D 2 ter:

fan. purge. unlooſe. fan. garner.


OF THE GOSPELS. 207

JOHN XIII.

29 For ſome *of them* thought, becauſe Judas had the purſe, that Jeſus had ſaid unto him, Buy *thoſe things* that we have need of againſt the feaſt; or, that he ſhould give ſomething to the poor.

30 He then having received the ſop, went immediately out: and it was night.

31 Therefore when he was gone out, Jeſus ſaid, Now is the Son of man glorified.

32 If God be glorified in him, God ſhall alſo glorify him in himſelf, and ſhall ſtraightway glorify him.

33 Little children, yet a little while I am with you. Ye ſhall ſeek me: and, as I ſaid unto the Jews, Whither I go, ye cannot come, ſo now I ſay unto you.

34 A new commandment I give unto you, That ye love one another; as I have loved you, that ye alſo love one another.

bag. 31 Then

Figure 2. Pages 19 and 207 of Priestley's *Harmony of the Evangelists* of 1780. Aligning the four Gospel accounts according to time, using between one and four columns per page. Chetham's Library, Manchester. Used with permission.

Priestley had already noted in his *Description of a Chart of Biography* how empty space has meaning. Rather than, as for Sterne, being a place for readers to insert their own data or imaginings, these empty spaces which arise automatically from the mechanical plotting of time to space reveal to Priestley the disastrous absences of knowledge-production in the Dark Ages: 'the thin and void places in the chart are, in fact, not less instructive than the most crowded, in giving us an idea of the great interruptions of science, and the intervals at which it has flourished.' The introduction of a mechanical model of historical time is crucial to revealing these patterns, clusters, drifts and absences. What Poole calls the 'lumpish quality of time'[33] of previous centuries, with its uneven succession of periods of different qualities, has been replaced by a Newtonian model where time is an absolute, neutral and uniform container for events (see Boyd Davis, Bevan and Kudikov[58]). As a result the patterning of events over time emerges.

Joseph Priestley is linked to Barbeu-Dubourg by a shared friendship with Benjamin Franklin, whose works the Frenchman translated. Mechanical methods for handling knowledge emerge equally in a letter from Franklin to Priestley. Writing to his friend from London on 19 September 1772 in response to a request for advice, Franklin, instead of answering the question, outlines his 'moral or prudential algebra.'[34] A miniature of Bentham's later Felicific Calculus, it is a method for balancing all the weighted advantages and disadvantages of a course of action on a single sheet of paper until a clear preference emerges. Like Priestley's innovations in diagramming time, it depends on having all the data in view and organised on a surface according to a mechanical system, and emphasises the automatic emergence of visual sense. Both the information handling, and the resulting cognition, are mechanised.

Mechanical culture

Today it may be difficult for us to enthuse about mechanical uniformity, but this was one of the great cultural innovations of the 18th century – though admittedly with deep roots, for example in the shift from hours of unequal length to those measurable by clocks (Dohrn-van Rossum[35]) or the aural uniformity introduced by the ticking of Huygens spring mechanism in the 1670s (Sherman[36]). The 18th was the century of Tull's improved design of seed drill which, though not widely adopted, would have been familiar in 'improving' circles like Priestley's: hand-broadcast seed was replaced by multiple parallel lines of plants. Natural watercourses were mechanised through the canal system, with over 3,100 miles of canal built in Britain between 1760 and 1800.[37] Urban terraces in improved cities like Bath and Edinburgh employed simple repetition and equality of every unit in the façade. Even pavements, until mid-eighteenth century in Britain the responsibility of individual householders and therefore of different heights, materials and quality, began to be replaced by uniform paving funded through local taxation.[38] In terms of measurement, it was in 1758 that a standard Yard measure was first established in Britain,[39] while in 1752 Britain's calendar had at last been made uniform with that proposed by Pope Gregory XIII in 1582. Mechanical uniformity was a cultural innovation of the time. Sawday (p97) makes the interesting observation, that for machinery during the Renaissance period simplicity and efficiency were not important criteria: complexity of design was to be welcomed. It is the 18th century which sees the emergence of a machine aesthetic as we would recognise it: the rigour and abstemiousness of the Barbeu-Duburg and Priestley timelines are a part of this trend in visual culture.

As Shaffer shows, the principles of mechanisation encompassed such apparently diverse fields as the world of entertainment and the factory system.[40] 1759 was the year both of Van Kempelen's mechanical chess-playing Turk and Arkwright's patents for the spinning frame. At its worst, machine inspiration resulted in proto-Taylorist images like Adam Ferguson's: 'Manufactures, accordingly, prosper most, where the mind is least consulted, and where the workshop may, without any great effort of the imagination, be considered as an engine, the parts of which are men.'[41] Incidentally it was this same Ferguson (1723-1816) who created another early timeline, the first to appear in the Encyclopaedia Britannica (2nd edition).[42] Perhaps the timeline and the mechanical vision of the workshop are two indicators of a single informing fondness for the machine. One of the students whose thesis examination Barbeu-Dubourg chaired, in February 1768, would later give his name to a famously mechanical engine of death: Joseph-Ignace Guillotin.[43]

The application of mechanical uniformity to chronography created new problems of its own, including the extent of nearly blank paper. Because of the long timescale of Barbeu-Dubourg's chart (he starts with the Creation in 4700BCE while Priestley starts at 1200BCE), his readers are presented with rather a large area of nothing very much: there are almost no persons or events in the first eight sheets of his long timeline. Priestley explicitly says that if he had begun earlier, 'I should have had no names [of historical figures] for the greatest part of my divisions.'[44] The new format could not accommodate the fact that there is almost always more data available for recent times than for the distant past, and that this would seem to require some kind of non-linear 'perspective', where the nearest time is assigned more space. Also the very neutrality of these mechanical approaches seemed to some to diminish their ability to 'tell a story'. Though the clustering through time, combined with the grouping into countries and categories common in such visualisations, had evident explanatory power, it seemed to other author-designers rhetorically inadequate. They generally abandoned the abstemious mechanical plotting of lifelines to time for richer visual forms. So, as Rosenberg[45] highlights, Strass specifically objected to the flatness and neutrality of Priestley's view, favouring a highly authored, hand-drawn grouping and linking of currents and tributaries in the stream of time (Figure 3).

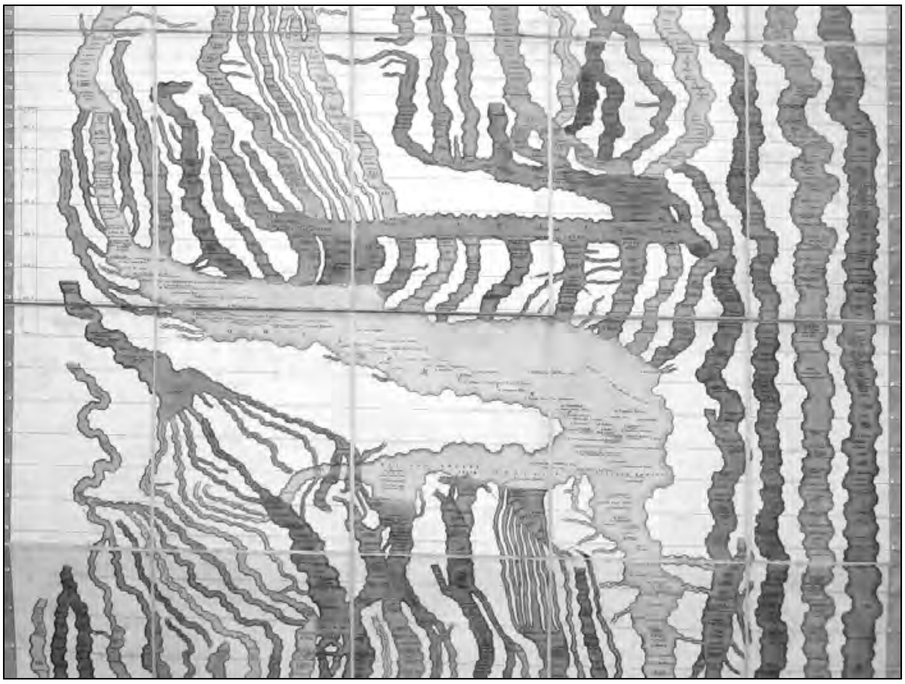

Figure 3 Strass,, W.H. 1849. *Stream of Time, or Chart of Universal History.* 1849. [London]: C. Smith, Mapseller. Detail. The mechanical neutrality of Priestley's chart is replaced by the rhetoric of hand-drawn rivers of time. Collection of the author.

But must mechanical approaches to visualisation lead to something obviously machine-like, with the limitations that seems to imply? It is instructive to look for a moment at the earliest days of computing as conceived in the minds of Babbage and Lovelace in the following century, the 19th. When Babbage made his well-known remark that astronomical tables should be calculated by steam[46] he clearly invoked the mechanical as a way of eliminating human weakness in ability and performance. Yet as Schaffer recounts,[47] there was quite another side to Babbage's concept of the machine. Babbage as a boy fell in love with an automaton dancer which years later he was able to purchase. He put her on a glass pedestal in his Marylebone salon in the room next to the unfinished portion of the Difference Engine. He also owned a silk portrait of Jacquard, the inventor of the punched-card system for programming looms, woven on just such a loom by Didier-Petit and Co of Paris.[48] It represented the subtlety and apparently humanistic qualities achievable with a mechanical (indeed binary) system. Meanwhile Babbage's mathematical collaborator Ada Lovelace took another significant step in writing that a mechanical system might compose elaborate music of any degree of complexity.[49] This 'other history' of machinery and computation is important when we consider the relationship between historiography and mechanism.

Though Babbage and Lovelace's thinking points to the future, their work also has echoes of the automata of the previous century, which intrigued by showing subtle behaviours while being mere machines. While perhaps to our eyes projects such as Vaucanson's automaton *Duck* and *Flute Player* appear bathetic, in contemporary accounts what comes across strongly is the desire to make machinery sensitive and subtle. The notes that Vaucanson wrote on his German Flute Player show that he had to acquire new knowledge about how the sounds of a flute are produced – to the extent that his notes are used today by musical scholars studying the flute playing techniques of the period.[50] Subtle investigation and transformation were essential to his working method, not 'mere' mechanisation.

In 1753 Barbeu-Dubourg went so far as to build an actual machine (*une Machine d'un usage facile e commode*) to house and present his historical timeline (Figure 4), describing it (hyperbolically as usual) as:

> a moving, living tableau, through which pass in review all the ages of the world, where each famous figure steps forth in his rank with the attributes belonging to him, where each Prince is surrounded by his contemporaries and occupies the scene for more or less time according to the duration of his role, where the rise and fall of Empires are acted out in visible form,
>
> (Barbeu-Dubourg 1753: 8.)[11]

The mechanical here adds a quite different quality of experience. While the aim of the new timelines was above all to create distance, giving the long view over time, what is claimed by Barbeu-Dubourg in this passage is something like immersion *in* history. These two modes of engaging with visualised time are both important. Unfortunately using paper technology, one tends to preclude the other: only a small part (about 140 years' worth) of Barbeu-Dubourg's timeline is visible at any moment, and as a reference work it is severely limited by the need to crank slowly through up to 16.5 metres of paper to reach a particular point in history.

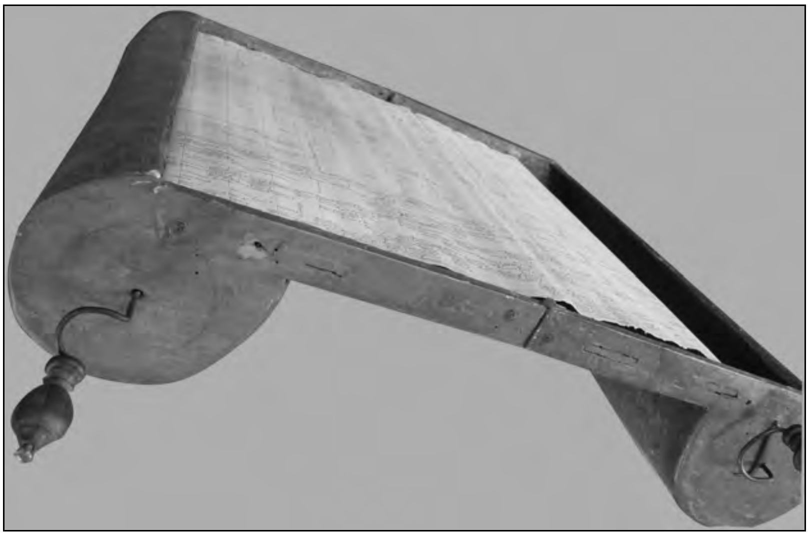

Figure 4. Barbeu-Dubourg, J. 1753. The *Carte Chronographique* housed in its machine. Rare Book Division, Department of Rare Books and Special Collections, Princeton University Library. Used with permission.

What now?

Chronology remains essential – 'the Thread of History, without which it is really nothing more than a Bundle of Detached Fragments.'[51] Any visualisations of time we create should enhance our understanding both diachronically and synchronically. As Priestley put it (1764), his chart showed how individuals 'stand related in point of time to one another; [giving] a clearer idea of the time in which they lived, the relative length of their lives, the state of their cotemporaries [sic], and the intervals of time which elapsed between them and their predecessors and successors.' Visualisation abstracts and simplifies: we can never hope to capture the complexities of the real world, or even of the historical record, in a graphical representation. But if we are to harness the machine of our time, the computer, to represent these data, then we must not reduce the complexities of history to simplistic representations, squeezing out in the process all that is most interesting about historiography.

Historical events, whether individuals' lives or other occurrences, have several important features. They are seldom discrete; they often possess an implicit hierarchy so that, for example, the works of an author belong to the lifeline of an individual which may in turn belong to a school or period. A single one of the author's works might have multiple editions; there may be a day-by-day record of the development of each draft. Events in history are known with widely varying levels of precision. One event may belong to one or more others, perhaps with different degrees of 'ownership'. Crucially, the facts of history are often disputed. Most of the generic forms of data uncertainty identified by Pham, Streit and Brown[52] affect chronological material, including limited accuracy, missing data, incomplete definition, inconsistency, personal bias, ambiguity of description, and embedded assumptions. We cannot afford to hide these complexities, yet most chronographic representations present their data as if it were both precise and undisputed. As one would expect from a subtle and original thinker, Priestley recognised and at least partly dealt with several of these problems in 1764. He graded uncertainty in five levels: a solid line represented dates he regarded as certain; a single dot below one end of a lifeline expressed some doubt; replacing the end of a lifeline with one, two or three dots expressed further degrees of uncertainty. It is hard to find a timeline now which acknowledges such problems.

What else can the computerisation of chronography do for us? It has a potentially transformative effect on how the user navigates and interacts with information: it should be possible to overcome many of the difficulties associated with physical timelines. Instead of having to wind a handle to travel through time using Barbeu-Dubourg's machine, we can jump in an instant from one period to another. We should also be able to move rapidly from a close-up view to a wide perspective, or see views at different scales on a single display. Priestley recognised that the information needed depends on who is using the timeline and for what purpose. We can merge disparate datasets: Priestley tried to anticipate this too, by creating his charts of biography and of history on the same scale so as to facilitate mapping between them. The problems of scaling time that plagued the pioneers of visualisation can also be surmounted: at the user's choice, we can switch between linear and non-linear views of time, or even revert to the packed views which the pioneers made so much effort to replace with their uniform mechanical time. How time is mapped to space can be changed by the user depending on the needs of the moment. By making the timeline an interface to additional data, limitations of information depth and of precision can both be overcome. Crucially, we can provide access to metadata, including an 'audit trail' of sources and revisions (Priestley acknowledged all his major sources, but obviously could not specify them on an individual basis for each event). This also makes it possible to present competing versions of events. Updates and additions can be made seamlessly. Using filtering techniques we can suppress information not currently needed and use a variety of visual methods to foreground the results of searches and other forms of selection. We can counter Strass's objections to the neutrality of Priestley's charts by allowing any kind of additional rhetorical material to be inscribed within the structure.

Where are the digital timelines that fulfil this agenda? As already noted, most 'timelines' in the Web are just chronological lists or tables: the machinery of page rendering means that packed lists and tables are all too easy to produce: the machine is equivalent to that of the late 17th century. If we wish to construct truly chronographic layouts we are generally in the hands of programmers and interaction designers, who may have little grasp of the issues outlined above.

Some progress has been made in creating general tools to turn chronological data into chronographic views, notably at MIT in *Simile*:[53] its facilities are as yet extremely limited. At least it allows two views to be presented simultaneously so that overview and detail are both available at once, overcoming some of the problems of scale. Southampton University's *Continuum* has some unusual features: chunks of time can be omitted, allowing two separate historical periods to be juxtaposed; and arcs can be inserted connecting any two items in the timeline, reintroducing some rhetorical elements into the mechanical array of events. A persuasive example of its use by André et al.[54] shows Bach's compositions attached to their various Glen Gould recordings, the intervening centuries being omitted. Plaisant et al.[5] devised a rich set of graphic encodings such as line width, tone and colour to add meaning to the lines of their *Lifelines* project. A timeline of photography by Kullberg[55] harnessed a powerful rendering system to create a 3D timescape of events, lifelines and associated objects: one of its most important features was the ability to move smoothly between a wide variety of scales of view. Manovich's Software Studies Initiative[56] offers many examples of mapping humanities data over time, demonstrating the value of chronographics for analysis, not just presentation. 3D chronography has been evaluated experimentally by Foreman et al[57] which suggests that there is still much to learn in terms of the cognitive benefits and pitfalls of these approaches. In terms of searching and selecting, advances have been made in a project directed by the author[58]: visual salience using highlighting and selective focus is used to present all search results in situ, so that the context of time is never lost and even unselected items remain just visible (Figure 5). This project is also highly unusual in visually representing uncertainty.

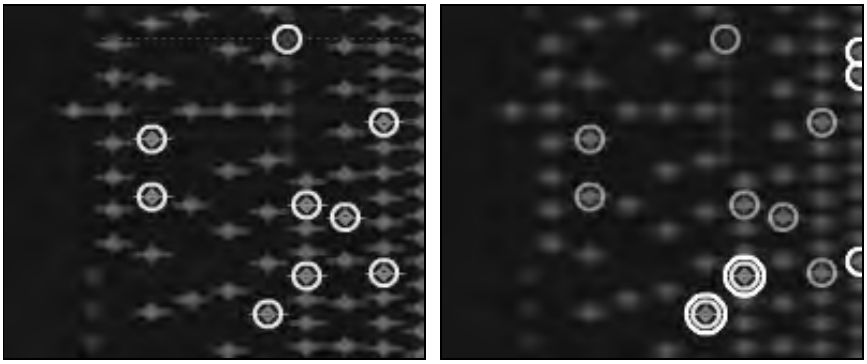

Figure 5. Emma Bevan and Aleksei Kudikov 2010: A timeline for the Museum of Domestic Design and Architecture at Middlesex University (detail). Visual salience is used to identify search results: left, designs containing trees are highlighted; right, designs with trees and fruit. Used with permission.

Though each of these advances is helpful, much remains to be done before we can say we have a toolkit worthy of historical research and presentation, something which can represent the subtle, humanistic, richly interpretive world of history indicated at the beginning of this paper. Just because computers deal easily with certainty, we pretend graphically that out data are sure, precise and uncontested. Simplistic use of machines produces simplistic representations of knowledge. The excellence of thought and practice from the early days of visualisation suggests that we need to be more ambitious in our conception and construction of chronographics, and more demanding of the tools devised to build them.

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