Marey, the analytic, and the digital

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Etienne-Jules Marey used to fit into a neat category, as a Muybridge-like French scientist of the late nineteenth century, best known for his chrono-photographic gun, a device capable of capturing complex movements like the wings of a bird in flight. This view comfortably labelled Marey as 'pre-cinema', for his creating a device that wasn't quite movies, but a step in that direction, culminating in the Lumière (who used to provide photo supplies to Marey) invention of real movies as we know them.

Thanks, in large part, to the masterful work by Marta Braun, the broader dimensions of Marey's achievements and influence have become better known, and Marey has begun to pop up in an unusual array of places.[1] My own discussion here stems from realising that the Marey discussed by Edward R. Tufte in *The Visual Display of Quantitative Information* as a classic figure in information design and the pre-cinema Marey were one and the same.[2] I would like to use this interesting overlap of Marey's interests to add another possible way to consider his achievements – as someone not just anticipating cinema, but whose thinking is very close to important notions in digital media as well. I also wish to offer an alternative view to the notion that the Lumière invention of cinema arose from their successfully moving beyond Marey's work. Instead, it is possible to view Marey's vision of movement and the chronophotograph as a fully realised theory of the analytic and visual role of the media he developed and worked in, rather than as primitive pre-cinema. One could as well see Marey's ideas as an expression of a view of cinema which was squelched by the direction taken by the Lumière brothers, but which one finds persisting to the present day.

The artist–scientist

Towards the end of her book on Marey, Marta Braun makes the apt comparison with Leonardo da Vinci (in a final chapter offering useful explanations for Marey's relative obscurity).[3] Concluding that his obsession with movement throughout his career hindered an appreciation for the range of his accomplishments, she signals an idea that might be inverted to identify a significant facet of his genius. 'Movement' as a word conjures up equally the artistic and the scientific. The dancer, the athlete, the beating heart, the gallops of a horse's hooves, the tracings of a figure through space – all can suggest a simultaneous desire to capture and to analyse. Marey's obsession with movement was an obsession of representation and measurement. Had he stopped at either, he would indeed be a nineteenth-century footnote. Instead, it is the nature of his analysis, the quality of his thought, indeed the bridging of concerns across art and science, which make him truly Leonardo-like. Indeed, part of his obscurity has come from this difficulty of pigeon-holing, and perhaps also because as his scientific contributions were so extensive, his aesthetics have attracted less attention.

Marey's special contribution I would sum up as follows: he developed tools to realise his ideas about how complex physical processes could be analysed. By analysed, I mean how

these processes can be visualised and explained in discrete terms. Marey didn't just measure. He developed a system of thought about how to reconcile the disparity between what we think we see and what could be verified, especially as it applies to events beyond unaided perception (the wings of insects, the blood in our veins). This system evolved to include graphical representations, temporal charts (chronographs) and photographic representations of movement over time (chronophotographs). This is an arc of evolution, a continuum, not a series of jumps, a path itself to be traced.

On anticipating technical change

To speak of Marey anticipating the digital requires some discussion of what anticipating technological change means, and why it is worth observing. I would start in the Bazinian mode, along the Myth-of-Total-Cinema line of 'the cinema of the future hasn't yet been invented', to explore notions of the possibilities in the conceptualisation of what cinema can accomplish, rather than the dominant commercial directions which the invention took.[4] Just as early cinema anticipates widescreen, colour and sound, one can argue that Marey's ideas of movement led to a view of the medium only now just being realised, but which are essential to his own notion of his form of cinema, his medium. The other part of Bazin appropriate here is his most astute view of directors like Renoir, Welles and Rossellini as bridging significant technological change through an aesthetic which incorporates a broader understanding of the medium, putting the conception of the medium above the transitory nature of the technology at any given moment. Linking the montage style of *Paisà* to the deep focus of *Citizen Kane* is the insight which can be applied to how Marey's notions of movement are consistent with recurring concerns in digital media.[5]

What are digital media?

Just as considerations of cinema are too often restricted to the narrative fiction film, one can as well ask what does it mean to talk about the digital, especially at this still-early point in its development. I would treat digital media

in a very literal sense, to say simply that which is processed in some manner by a computer. This would then include CD-ROM and DVD forms of entertainment and information, as well as all the tools of 'processing', the Photoshops and the Words, the Premieres and the 3D Studio Max's. And, of course, the Internet is currently the most public and influential form of digital media. One can say that digital media have blurred the line between work and play, between science and art, between product and process. I will point to some specific aspects of digital media to which Marey has great affinity, but it is important to note that the digital in 2004 is about where film was in 1898: invented, as it were, but not yet in a dominant form. So we would do as well to speak of the myth of total digital media – expressions of an idea not yet fully realised.

Should movies move?

To understand Marey's genius, one must not see his work as pre-cinema, but as an alternative system. Cinema as an analytic tool might well be a non-illusionist medium closer to Marey than Lumière. That is, Lumière's cinema was a step backward (or at least away) from discovering forms of representation which were superior to everyday perception. Marey does not seem at all interested in the life-like; rather, he finds ways conceptually to display traces of movement hidden or obscured by everyday perception. Most ironically, in order to understand movement, he was not a strong proponent of movies moving. To see why this was not a contradiction will take us through a brief survey of his thought, but it is important I think to see at the outset that the link from Marey's media, the graphs and chronographs and chronophotographs, on to Lumière's cinema is not necessarily technologically inevitable. The invention of cinema is not a more advanced idea than Marey's, and to the question of whether movies should move, one might well answer, with Marey, not necessarily.

The graphic method

Marey's 1887 work, *La methode graphique*, is an extraordinary near 700-page treatise on methods to graph a wide range of phenomena, from train schedules to weather, to sounds,

to periods of war and peace. Summing up existing work to that point and offering a good deal of his own, Marey was concerned with how to represent change, already a larger idea than simply depicting movement, though certainly incorporating it. A key notion is to see Marey as an artist-scientist of space-time, and to view his obsession with movement in that context.[6] Edward R. Tufte pays appropriate homage to Marey in the first of his now three great books on information design which together represent a real advance in thinking in this area – one master recognises another.[7]

One quality Marey expressly valued (as Tufte recognises) is the central notion of the all-at-a-glance chart: the single image which brings out a complex activity which would otherwise lie unobserved. We could as well be talking about a painting when Marey celebrates the detail and originality in an engineer's rendition of a Paris-Lyon train schedule in graphic form. Even from here to Duchamp's *Nude Descending a Staircase*, the most famous art work directly inspired by Marey's later chronophotographs, is but a short step, as it were. A visual hallmark of all of Marey's work is a dense compression of visual information – his was a science-art of overlap, collage, simultaneous frozen motion, multiple viewpoints. This love of serial overlapping seems to be both an appreciation of its intrinsic elegant beauty and to have an overriding goal of how sense could be made of the patterns which resulted when minor variations were graphed over a neatly designed set of parameters. The brilliant Marey chart was a database made strikingly visual through a recognition of pattern repetition.

There is another clear component of digital thinking here – the barely measurable was being transformed into *discrete* variations – the analogue was giving way to the grid. To affix a point in a graphic space, to assign co-ordinates, is to digitise in the best sense – especially when that grid did not simply represent the x, y or z of 3-D Cartesian space, and also when that graph might also move over time – an unfolding histogram of the poetry of repetitive movement. The numerical calculus of movement became points in time and space to be represented, travelled through, reconfigured, transformed.

From the graph to the chronograph

Marey didn't jump from the graph to the photograph, an important step intervened which also shows a mind thinking digitally. Marey was a pioneer in developing devices for automatically registering movement – recording-strip-like machines which sometimes unspooled their results in a manner spookily like unwinding film. When one sees the line-patterns of horse hooves or the record of a pianist's key presses,[8] it is as if one is seeing a McLaren or Brakhage work drawn directly on celluloid.

What is intensely cinematic about these pre-cinematic works is that they reveal the pattern variations which are inherent in any strip of film which contains movement – held to the light, they are a series of subtly discrete variations of a single act. In Marey's chronography the variations are of hoof distance or heartbeats – but they teem with movement without any photorealistic elements – they are essentially lines and bar charts and patterned icons. The movement is in variation and spacing. We would do well to notice that this essence of cinema – the slight variations of a basic visual component – are what make digital video compression possible. In most such schemes, only the changes from frame to frame (the so-called delta) need be stored to reconstitute the moving whole.

Marey appeared to be looking for a kind of automatic process of transfer of information, a mode which would be both as direct as possible and would still provide an appropriate form of representation. While his later chronophotography of the paths of birds' wings is amongst his most known feats, less known are his remarkable earlier experiments directly connecting live birds to a graphing machine to trace patterns of wing movement.[9] Rather than impede or freeze motion, Marey wanted to capture data at discrete regular intervals which could then serve to reconstruct (one wants to say deconstruct) the original action.

A form of amazing symmetry to his bird experiments came with what Marey called his 'Solid Figures in the Zootrope'. To quote him on this departure of his from the conventional nineteenth-century spinning illusion device: 'Instead of a strip of paper covered with fig-

ures, we introduced into the zootrope a series of wax models painted in oils, and representing the bird in all the successive phases of its wing movement. The illusion was complete, and a flying bird could be seen flying round the apparatus; sometimes flying away from the observer, sometimes across, and sometimes toward him.'[10]

Taking apart and putting back together is not the same thing as simply recording or capturing. The zootrope-with-sculpture is one kind of apt metaphor because Marey would want the viewer to look as much from above as through the slots. The overhead view offered the breakdown into successive moments of movement – the analysis, as it were. The re-creating view through the slots would be the confirmation of the soundness of the analysis, the chance to step back through the experiment, the laying out of the proof. It barely need be said that one would not expect a series of bird sculptures from a scientist,[11] but in a figure in the mould of Leonardo we shouldn't be so surprised.

The chronograph also lays bare the serial which had been seen in a more elemental manner in the graphs – the rises and falls of the repeated pattern which may be regular or greatly varying over time. The heartbeat, the movements of a muscle, the patterns of sound, reveal unfolding visual rhythms of highs and lows. Numerical data as a river of visual measurements is highly revealing of underlying structures. The 'at-a-glance' characteristic holds true of these as well – relationships become quickly evident where long columns of numbers could not have revealed their patterns so easily, clearly, and extensively.

The serial can also be described in terms of succession and synchronism, terms Marey himself used with some precision and which, while they would reappear in relation to the chronophotograph, were already clear principles for the chronograph.[12] Both sound already cinematic in that Marey described a method of revealing patterns by noting the changes resulting from overlapping successive traces to bring out unfolding patterns. The charting of repeated movements with special attention to visual techniques sensitive to displaying those temporal relationships of occurring one-after-another and both-at-the-same-time, along with consideration of quantitative difference (how much, how hard, how separate, etc.) shows Marey quite aware of the implications of this kind of study.

The chronographs also bring out another dimension of where Marey's analyses were leading. As Braun puts it, 'As was typical of his methods, Marey made the transition from describing the movement to measuring the forces that determine it'.[13] Movement as such, while celebrated and calibrated to a high degree, was not the sole or final objective. As Braun later traces this direction in Marey: 'He entered more deeply into the domain of physics proper.'[14] Movement stands in relation to energy as visual elements in cinema (tracking shots, close-ups, etc.) relate to style – a significant component of the larger picture. Marey was analysing movement to place it within the context of energy production and expenditure, in other words, of life processes in their totality. Thinking in terms of force fields or matrices of energy would better tease out the complex structures Marey was revealing. Mapping quantities and durations of subtle physical processes was a way to understand how the body (animal and human) and the world worked.

The chronophotographic impulse

Before photography entered into this activity, then, Marey had already mapped out a scientific-artistic method of thought and vision. What did photography bring to this method? In 1885, Marey described his photographic work in a small supplement of about thirty pages to his *Methode graphique*.[15] In his landmark 1894 book, *Movement*, Marey is also careful to place his photographic work as an extension of his 'graphic record of time' and to point up not just advantages but shortcomings of this change. In general, one could say that Marey was more interested in the camera as a sometimes more accurate recording tool – one more technique – than as an inevitable technological progression.

In the supplement, choosing his words most carefully, I would say, Marey qualifies and places as follows: '... photography, like all forms of graphic representation, is a faithful memory which preserves unaltered the im-

pressions it has received' and just after speaks of how these 'immutable documents' can serve in the comparative analysis of movement.[16] The photograph, then, is praised for its (obvious) recording capabilities, but only one tool among other methods of graphic representation, citing it for the forms of possible accuracy it brings. At the same time, in the true manner of a scientist, Marey spots potential pitfalls. Perspective issues, for one, come up almost immediately in *Movement*, with Marey seeing limitations in the 'one eye only' of the camera, and suggesting the needed 'recourse' of stereoscopic pictures, something Marey had experimented with a number of times.[17]

It's also important in itself that Marey saw photography more as a graphing technique than as a superior form of visual representation. The most brilliant component of Marey's use of photographic methods is that his chronophotographs are still a form of visual graphing, a mapping of data for analysis, and are not in themselves conceived or meant to be solely a scientific record. This alone would place him worlds away from the Lumière films, celebrated for being documents of motion and realism. Marey's chronophotographs are constructed to reveal the hidden, not to record the already visible.

Crucial to this method was his technique of mapping points and trajectories, so that what unfolds over time in an image is another form of the trace – a series of lines and points, superimposed as it were, over the likeness of the body producing them, the superimposition becoming so dominant as to take on life as a pattern of representation of its own – patterns that would dominate the figures in works such as those by Duchamp which followed Marey's manner of seeing. When Marey described this aspect of his work as 'geometrical chronophotography' he was explaining this well, as also when he spoke of 'artificially rendering the surface of the object under observation'.[18] In other words, the body would distract from the observation of its movements. Marey's captions for his work approach the conceptual elegance of a later artist like Sol Lewitt, as in 'Image of a runner reduced to a system of bright lines for representing the positions of his limbs' or 'Chrono-

photographic trajectory of a flying apparatus describing a sinuous curve in the air (20 images to the second).'[19] It is as if the idea of movement must be abstracted from the particulars which photography would make overly distracting. A process of visual reduction was needed to arrive at an essence.

Chronophotography and cinema

The chronophotograph could be seen as in the mode of digital thinking in that, by its very nature, it breaks down a continuous, on-going activity into a set of measurable, discrete components. Having been thus captured, the action is subject to reconstruction, to further analytic study, to being understood and appreciated for its complex set of movements.

Were chronophotographs crying out to become cinema? Braun does a brilliant job of chronicling the intersections between Marey and the Lumières (and Edison), as well as discussing at length the Marey experiments at producing moving chronophotographs and the activities of Marey's assistant-protégé, Georges Demenÿ, who had some interesting schemes of his own, like the annotated family portrait, which seems to have a modern-day counterpart in the many family pages (and annotated GIF's) of the Internet.[20] I would say that what emerges from Braun's account and Marey's writings is at least an ambivalence on Marey's part toward the necessity or need for motion. This problem became complicated with issues of projection (which are not the same question as producing the illusion of motion itself), which quickly was seen to have clear commercial value, but which Marey did not seem to be as interested in for scientific purposes.

What is important here, I would say, is the idea that motion, by bringing us closer to everyday perception, would be inherently less analytic. Chronophotographs were never like still frames of a movie-yet-to-be-projected. Here Marey is distinguishable from Muybridge, I would say, whose series of successive camera images would suggest continuous motion more fluidly and easily. To make the chronophotograph move is to destroy its essentially analytic nature. It is completely consistent, and most enlightening, to know Marey, when interested in the moving

picture, was more intrigued by fast and slow motion.[21] And in a most astute summary of the problem, quoted by Braun with original emphasis by Marey, he said, 'The most appealing chronophotography is *not* the most useful'. In that sentence is contained so clearly and almost poignantly the tug between the scientific-analytic and the commercial which has characterised the invention of cinema. As Peter Wollen (and others) have pointed out, cinema as a commercial entertainment was shared in the early days (well into the 1920s) with a tradition of scientific film, one of the kinds which began in kinship with Marey.[22]

Another purely analytic (and brilliant) Marey experiment, again turned over to his assistant Demenÿ, demonstrates once more Marey's capacity for breaking down a process into component parts, in a manner which could reconstitute the original movement. Begun as a project to teach speech to deaf children, the filming of short phrases as a series of still images shows Marey's thinking applied to something other than purely physical movement expressed through the chronophotograph. The components of speech could be isolated only by determinations of what constituted isolated actions – Marey's analyses always made determinations as to what were the units of significant movement – this indeed was the analysis. As in the digital world, the translation into images required a capture strategy which was far from purely mechanical. The images which made up the analysis of speech could be returned to an illusion of movement (which Demenÿ did with his phonoscope, a device to project these pictures of a person talking),[23] but was that result a desirable form of cinema? It is, in this case, the series of images which are the revelatory experience, just as with chronophotographs, it is the simultaneity of the unfolding of movement, represented by each stage of that movement, which are so revealing and beautiful. As François Dagognet puts it, 'Marey preferred analysis to synthesis'.[24] And synthesis, one must conclude, meant cinema.

Chronophotography and the digital

Why then, is it useful to discuss Marey in relation to digital technology? Hopefully, there has been an argument building here that Marey's methods are not confinable to a single point of technologic time, and that the aesthetic-scientific sensibilities he displayed are consistent with the potential for the digital, which I would define as being a step (back?) toward the analytic, and away from the mechanical-photographic reproduction of movement for its own sake which is much of what constitutes cinema. The digital returns the notion of the discrete time-space which was Marey's habitat, and also displaces a dependence upon real-time linear presentation and the chemically- (or electronically-) based realism of cinema (or video). The digital is also clearly an analytic medium in its exposing (even revelling in) its own constructions, and a step back from the nineteenth- to twentieth-century 'progression' of photography-film-video. The digital is a medium finally not celebrated for its mechanical realism.

Starting with the computer as a digital media creation machine, it can be looked upon as a pixellated simulation engine – in fact as a kind of chronophotographic gun itself – as it captures motion through a process of serial overlapping images. While our desktop digital world is only starting to move from the slightly jerky video at far from film-like resolution of the last few years – the image, even at better quality, still comes across as a non-lifelike reproduction of a motion to be broken down. The slider which can be offered with most digital video on the desktop is also pure Marey, dragging and pausing to view successive frames. It could be seen as one form of motion not in contradiction to chronophotographic aspirations. Video on the desktop is never the immutable passing of real time; it is the image ready to be arrested in flight like one of Marey's birds. And the digital video and movement we see is ready to be blown up (its pixels expanded in size), reformulated (speeded up, slowed down, filtered), or recompressed. New developments in digital video, like DVD, include features such as the immediate switching between multiple perspectives, a kind of cubism in motion.

One key may be found in the idea of capture, a term essential to Marey and the digital. Physical phenomena aren't reproduced, they are stalked and won. When captured, they are
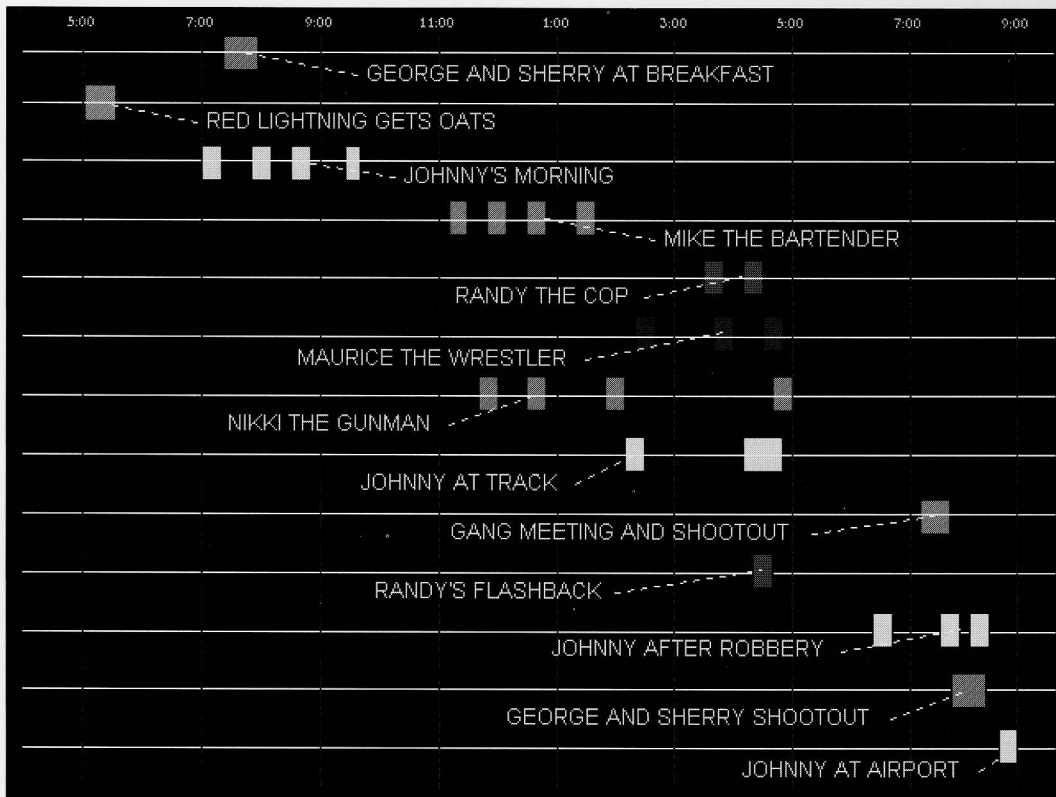
Fig. 1. Temporal ordering in Stanley Kubrick's The Killing. *Each horizontal line represents a successive narrative segment for an individual character, and charted horizontally are the time positions of each segment for that character, so the order in the film reads down from one horizontal line to the next, stopping at each line, from left to right, before succeeding down to the next line.*

creatively re-simulated, displayed almost as trophies. Elusive movement, complex patterns, subtle temporal-spatial relationships are presented in a framework which can make the familiar fascinatingly detailed and strange. The digital, like the chronophotographic, carries with it the sense of rediscovery through reconstitution. Rather than a likeness of reality (as in the cases of photography, cinema and video), these offer a way of looking and experiencing which appropriates that which it has reproduced and competes with the original, which now looks palely unreflective by comparison. The conversion of the analogue to the digital is not just quantifying; it is translating, reformulating, and offering up an alternative vision. The walkthrough, the model, the mapping, the graphing, the visual representation of analysis is the lure of the constructed digital world. An information space, a database, a toolkit, a storage device, a set of interfaces – are we talking about Marey's nineteenth century or our own early twenty-first century?

That 3-D modelling and walkthrough activities are becoming prevalent (*Myst*, VRML on the Internet), almost commonplace, is an area where Marey is still ahead of his time. Motion capture is Marey brought to the digital, and one waits expectantly for uses of these methods for purposes other than to produce cheap animation by capturing the motion of a performer robed in a Marey-like apparatus for recording points in space rather than by drawing or modelling that motion. The notion of real-time rendered 3-D space, of wireframes texture-mapped to make them convincingly explorable, from multiple perspectives (as current 3-D software also easily allows) owes much to Marey, especially as we move from an invisible point-of-view with no observer into a cyberspace world of actual bodies in motion.[25]

The wireframe is another key point of commonality as it represents the reconstitution of a component structure. Marey's chronophotographs can look like mobiles, successive frozen moments engender path-like trajectories. Akin to capture is another aggressive verb: to scan. In 2-D, scanning brings still

images and text into the digital realm. In 3-D, scanning is a process akin to travel through the looking glass; objects move rather magically into the acquisitive virtual space of the computer. Of course, 3-D models need have no physical basis (any more than do 2-D images), but there is a compelling sense of underlying frameworks made visible, so objects are truly captured in the process. Just as animation requires analysis of movement, in a sense retracing Marey, modelling the world means acquiring, measuring and re-presenting it. (3-D software is an animation engine among its many powerful attributes.) Preferring the wireframe to the fully rendered, the 'broken down' movement to its smooth presentation, the visible pixels to the clear image are ways of expressing a preference for seeing what makes things tick rather than just watching the things themselves.

As one final form of linkage, I think one can argue as well that Marey's notion of graphing methods (encompassing the chronophotograph) as a form of information technology not only accounts for Tufte's admiration but can be detected anywhere in the digital world where visual databases have sprung up, especially as represented by a spatial interface. Whenever numerical data (or textual information, for that matter) become part of an x,y,z co-ordinate system in place of a spatial referent, or external data (especially when temporal in nature) are mapped into a visual space, we have to see a use of technology closer to the chronophotograph than to the cinema of Lumière and most of the twentieth century. As an example, I offer a chart of narrative temporal relationships in Stanley Kubrick's film *The Killing*, as being in the style of Marey's graphic thinking (Fig. 1).[26] The kind of multimedia which uses graphical representation as an interface, or treats the components of a film as elements of a database, displays an analytic sensibility in their use of the digital. The all-at-a-glance graphic style of Marey is a forerunner of the visual compression implied in digital layering (showing you more than you can handle at the same time that you see all you need to know), new relationships made visible in aesthetically beautiful patterns of information.

Conclusion

My goal, then, has been simply to suggest that the technology, scientific thinking and aesthetic sensibilities of Etienne-Jules Marey can be more fully realised in a digital environment in that affinities to him are much in evidence in how that environment is forming. He has received somewhat short shrift in the cinema age because chronophotographs could be falsely viewed as movies-without-enough-simulated-motion, and in that view, then belittled. The true age of analysis, of representing complex phenomena with some accuracy and in visually challenging ways, will hopefully characterise the early part of the twenty-first century as much as it did the late nineteenth.

Notes

1. Marta Braun, *Picturing Time: The Work of Etienne-Jules Marey (1830–1904)* (Chicago: University of Chicago Press, 1992).

2. Edward R. Tufte, *The Visual Display of Quantitative Information* (Connecticut: Graphics Press, 1990).

3. Braun, *Picturing Time*, 350.

4. André Bazin, *What is Cinema?*, vol. 1, trans. Hugh Gray (Berkeley and Los Angeles: University of California Press, 1967), 17–22.

5. André Bazin, *What is Cinema?*, vol. 2, trans. Hugh Gray (Berkeley and Los Angeles: University of California Press, 1971), 16–40.

6. See Mary Ann Doane, 'Temporality, Storage, Legibility: Freud, Marey, and the Cinema', *Critical Inquiry*, 22, 2 (Winter 1996): 313–343.

7. Tufte, *The Visual Display of Quantitative Information*, 34–36. (The train schedule is also on the cover.) The other Tufte books are *Envisioning Information* (Connecticut: Graphics Press, 1990) and *Visual Explanations: Images and Quantities, Evidence and Narrative* (Connecticut: Graphics Press, 1997).

8. Marey did not produce the piano charts himself, but presents them most approvingly in Marey, *Movement* [1895], trans. Eric Pritchard (New York: Arno Press, 1972), 13.

9. Etienne-Jules Marey, *La Methode graphique dans les sciences experimentales et principalement en physiologie et médecine* (Paris: Librairie de l'Académie de Médecine, 1885), 153; also François Dagognet, *Etienne-Jules Marey: A Passion for the Trace*, trans. Robert Gatelawics and Jeanine Herman (New York: Zone Books, 1992), 82–85.

10. Marey, *Movement*, 311.

11. Marey did other bird sculptures as well. See Braun, *Picturing Time*, 141. Also in Dagognet, *Etienne-Jules Marey*, 147.

12. Marey, *La Methode graphique*, 154.

13. Braun, *Picturing Time*, 136.

14. Ibid., 216.

15. *Développement de la methode graphique par l'emploi de la photographie* (Paris: Librarie de l'Academie de Medécine, 1885), 3.

16. Marey, *Movement*, 3.

17. See, for example, Braun, *Picturing Time*, 100.

18. Marey, *Movement*, 60–61.

19. Ibid., 61, 89.

20. See, especially, Braun's Chapter 6, 'Marey, Muybridge, and Motion Pictures', in *Picturing Time*, 228–263.

21. Ibid., 195.

22. Peter Wollen, 'Cinema and Technology: A Historical Overview', in Stephen Heath and Teresa de Lauretis (eds.), *The Cinematographic Apparatus* (New York: St. Martins, 1980), 25.

23. Braun, *Picturing Time*, 176–180. Also discussed with pictures in Dagognet, *Etienne-Jules Marey*, 156–157.

24. Ibid, 156.

25. Marey's important interest in multiple perspectives is discussed in Braun, *Picturing Time*, 47–48.

26. Also see my article, 'Simultaneity and Overlap in Stanley Kubrick's *The Killing*', in *Postmodern Culture*, 8, 2 (January 1998). Web address is ttp://muse.jhu.edu/journals/pmc/v008/8.2mamber.html.