Poster: Getting All Your Bats in a Row: Optimizing Layout in Chronophotographic Style Visualizations

Fedor A. Korsakov* Daniel F. Keefe†

Department of Computer Science and Engineering
University of Minnesota

1 Introduction

Chronophotography, a concurrent depiction of multiple states of an object photographed at uniform time intervals in the same visual context, can serve as a valuable technique to give an overview of a dynamic process (e.g. motion) in a static illustration. In this poster we present an algorithm that generates chronophotographically styled visualizations from large sets of still images, while reducing occlusion and aiming to increase efficient use of the available space.

2 Related Work

Animation may seem to be the most intuitive approach to the depiction of dynamic processes, and may facilitate effective presentations as demonstrated by Hans Rosling in his TED talks [1], but its effectiveness varies depending on the purpose of the visualization. Robertson et al [2] indicate that animation can be effective for presentation tasks, but less so - for analysis, while small multiples techniques lead to faster completion of analytical tasks with fewer errors.

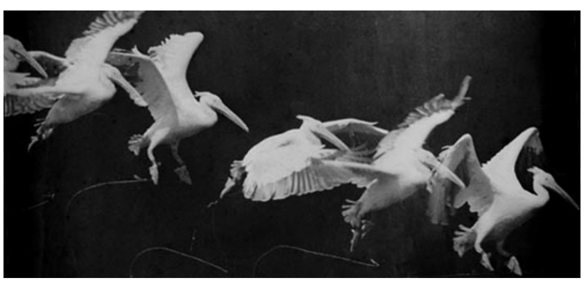

Figure 1: Étienne-Jules Marey, Flight of Pelican, c.1882

Small multiples and chronophotography share the concept of concurrent depiction of multiple states of the visualized object, the difference being that in the case of chronophotography, these depictions exist in a shared visual context whereas small multiples are typically placed in separate visual contexts. The parallel of analytical utility of the two techniques is strengthened by the fact that historically chronophotography was developed as a means to study motion [3]. Shared visual context facilitates discernment of spatial relationships between parts of the object as its state changes over time. Thus, it is clear that chronophotography is an analytically valuable visualization technique.

The standard approach of visualization design involves a progression from generality to specificity. Information is presented within a context that is established via an overview, and more detailed information subsequently is made available [4]. Chronophotographic style visualizations fit Shneiderman's mantra by providing an effective overview of the process of motion. Modern equipment allows recording of kinematic information at rates as high as 1000 frames per second [5], and effective analysis of such recordings necessitates using effective visualization techniques. Chronophotographic style visualizations may address the overview needs imposed by such datasets, but the high temporal resolution introduces a design consideration of selecting positions for the individual states within the image. Our work addresses this design consideration.

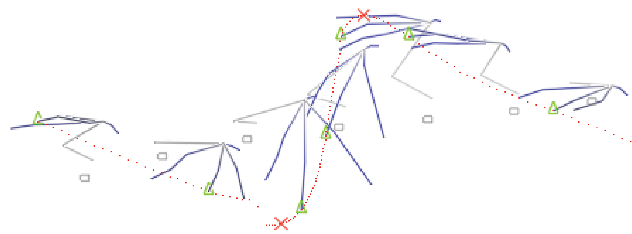

Figure 2: Wingbeat Cycle Of a Bat. A point of interest on the wingtip is marked with a green triangle. The path it takes is shown as a dotted red line. Extrema are marked with red X marks. Gray rectangles indicate the approximate position of bat's body, fingertips are colored with blue. Temporal spacing of 21 ms.

3 Our Approach

Our primary assumption is that accurate assessment of spatial relationships in chronophotographic visualization requires that each state of the object is perceived as being distinct, and that as many states are depicted as possible. Furthermore, the displayed subset of available information needs to closely follow the changes in the object's motion. In other words, the maximal number of states needs to be depicted with minimal overlap and maximal relevance to the described motion.

The dataset we used in this study consists of motion capture data from a bat flying in a wind tunnel, provided by our colleagues at Brown University. We are using a subset of the data: 350 frames of the 3D positions of structural markers positioned on the wing of the bat. These markers approximate the positions of the bones and joints in the wing. The data has been recorded at 1000 frames per second.

We propose an algorithm that automatically places the depictions of the states of the object by solving an optimization problem. This algorithm finds the upper and lower constraints on the positional gap, sets total distance traveled as the third constraint, and iteratively finds the spacing that satisfies these constraints while offering placement in the closest proximity to the extrema of the motion

*e-mail: korsa004@umn.edu
†email:keefe@cs.umn.edu

of a preselected point of interest.

The upper boundary is the maximal spatial gap (between pivot points) needed to display a given number of depictions with guaranteed zero overlap. The lower boundary is more dependent on the shape of the object. Looking at the historical examples, for example the work of Marey [3], it is possible to see that some overlap may not necessarily be detrimental, depending on the geometry of the object.

In order to find the lower boundary, we look at the distribution of current frame's markers between the center of motion in the current frame and the adjacent displayed frame. We find the distance equal to 2 standard deviations of markers' distribution, and then we compute the same quantity but for opposite direction in the adjacent frame. The two quantities are added together, and the greatest sum of these two quantities is determined for each possible spacing interval, yielding the value of the lower boundary.

The third constraint - net distance - is the product of the gaps between the depicted states and the length of these gaps, and is set equal to the actual traveled distance.

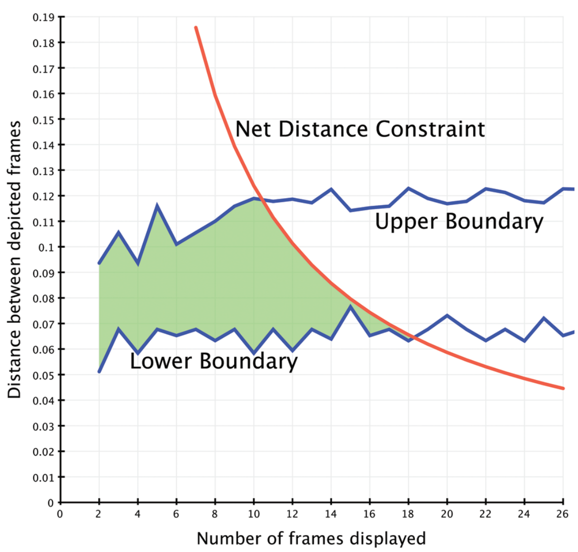

Figure 3: Constraints and the feasible region

The objective function $f(x)$ for our optimization is the closeness of the temporal spacing of total number of the depicted states x to the observed number n of extrema E_i of the object's motion.

$$f(x) = \sum_{i=0}^{n} \min \begin{pmatrix} E_i \bmod \lfloor \frac{350}{x-1} \rfloor \\ \lfloor \frac{350}{x-1} \rfloor - E_i \bmod \lfloor \frac{350}{x-1} \rfloor \end{pmatrix}$$

These extrema were acquired by finding the roots of the smoothed derivative of the position of a "point of interest" - typically a joint or a wingtip. Once the extrema were acquired, it was possible to select the spacing based on the lowest value of iteratively evaluated objective function. The use of iterative methods is facilitated by the fact that temporal position is expressed in integer values.

4 Discussion

As Figure 2 demonstrates, our approach provides visually acceptable results with even a single tracked point of interest. The algorithm is easily modularized and some future directions for possible research include tracking multiple points of interest, and adaptation for scenarios with more complex motion. The bat in our dataset moved in a highly periodic fashion, however it can be expected that aperiodic motion can also be accommodated. Formal user studies to assess the effectiveness of the visualization in comparison to small multiples that are placed in separate visual mini-contexts presents another area of potential research.

The technique has applications beyond illustration. A possible application lies in user interfaces for video player software. While direct manipulation for video navigation remains an active research area [6], chronophotographic style overviews of clip contents could facilitate interactions.

A possible concern with our approach is the reliance on uniformity of the interval between concurrently depicted states. In our opinion, this is a benefit to the viewer since it maintains a consistent frame of reference by expressing the change in time spatially. An alternative approach that emphasizes depiction of the key poses [7] may be more suitable for scenarios involving overviews of highly nonuniform motions, but such an event-based approach detaches the motion from the temporal dimension. Furthermore, and to some extent depending on the dataset used, if we are to view both methods in the context of Shneiderman's mantra, a chronophotography-based method that focuses on achieving plausible information density may perform less information suppression than an event-based method. Since we consider a general overview to be the primary goal of our technique, the uniform time interval is likely to satisfy this goal better.

5 Conclusion

We have presented an algorithm that allows extraction of images from a set of motion data in a way that builds on the successes of chronophotographic techniques. This style of visualization allows the viewer to have an overview of the motion data in a static medium and has obvious applications in the field of both scientific and general purpose (e.g. sports) illustration. The algorithm may be expanded to accomodate more complex motion patterns, which would further expand its utility.

Acknowledgements

The authors would like to graciously acknowledge their colleagues in the Department of Ecology and Evolutionary Biology at Brown University, especially Sharon Swartz and Dan Riskin for providing experimental data that inspired this project.

References

[1] H. Rosling, "Ted Talks: Hans Rosling shows the best stats you've ever seen," February 2006. http://ted.com.

[2] G. Robertson, R. Fernandez, D. Fisher, B. Lee, and J. Stasko, "Effectiveness of animation in trend visualization," *IEEE Trans. on Visualization and Comp. Graphics*, vol. 14, no. 6, pp. 1325–1332, 2008.

[3] M. Braun and E. Marey, *Picturing time: the work of Etienne-Jules Marey (1830-1904)*. University of Chicago press, 1994.

[4] B. Shneiderman, "The eyes have it: A task by data type taxonomy for information visualizations," *The craft of information visualization: Readings and reflections*, pp. 364–371, 2003.

[5] D. Riskin, D. Willis, J. Iriarte-Díaz, T. Hedrick, M. Kostandov, J. Chen, D. Laidlaw, K. Breuer, and S. Swartz, "Quantifying the complexity of bat wing kinematics," *Journal of Theoretical Biology*, vol. 254, no. 3, pp. 604–615, 2008.

[6] P. Dragicevic, G. Ramos, J. Bibliowitcz, D. Nowrouzezahrai, R. Balakrishnan, and K. Singh, "Video browsing by direct manipulation," 2008.

[7] J. Assa, Y. Caspi, and D. Cohen-Or, "Action synopsis: pose selection and illustration," in *International Conference on Computer Graphics and Interactive Techniques*, pp. 667–676, ACM New York, NY, USA, 2005.