USING TIME AS A SUSTAINABLE TOOL TO CONTROL DAYLIGHT IN SPACE

Creating the Chronoform

SAMER EL SAYARY
Beirut Arab University and Alexandria University, Egypt
samer.elsayary@alexu.edu.eg

Abstract. Just as Einstein's own Relativity Theory led Einstein to reject time, Feynman's Sum over histories theory led him to describe time simply as a direction in space. Many artists tried to visualize time as Étienne-Jules Marey when he invented the chronophotography. While the wheel of development of chronophotography in the Victorian era had ended in inventing the motion picture, a lot of research is still in its earlier stages regarding the time as a shaping media for the architectural form. Using computer animation now enables us to use time as a flexible tool to be stretched and contracted to visualize the time dilation of the Einstein's special relativity. The presented work suggests using time as a sustainable tool to shape the generated form in response to the sun movement to control the amount of daylighting entering the space by stretching the time duration and contracting time frames at certain locations of the sun trajectory along a summer day to control the amount of daylighting in the morning and afternoon versus the noon time.

INTRODUCTION

According to most dictionaries (Oxford, 2011; Collins, 2011; Merriam-Webster, 2015) Time is defined as a nonspatial continued progress of unlimited duration of existence and events that succeed one another ordered in the past, present, and future regarded as a whole measured in units such as minutes, hours, days, months, or years. As time is considered to be one of the seven fundamental physical quantities in both the International System of Units and International System of Quantities but it was not used to define the geometry of the architectural form. Time is used to define other quantities—such as velocity of the user inside the building —so defining time in terms of such quantities would result in a new formation that considers time as a parameter that shapes the architectural form. (Duff *et al*., 2002).

Fig. 1. Etienne-Jules Marey (1830-1904), Analysis of the Flight of a Seagull, 1887, Bronze, 16.4 x 58.5 x 25.7 cm, Dépot du Collège de France, Musée Marey, Beaune, France.

An operational definition of time that defines time in terms of a process needed to determine its existence, duration, and quantity would be more convenient to observe a certain number of repetitions of a standard motion event that constitutes one standard unit such as the second, is highly useful when it relates to architectural form that might be constructed on a grid module.

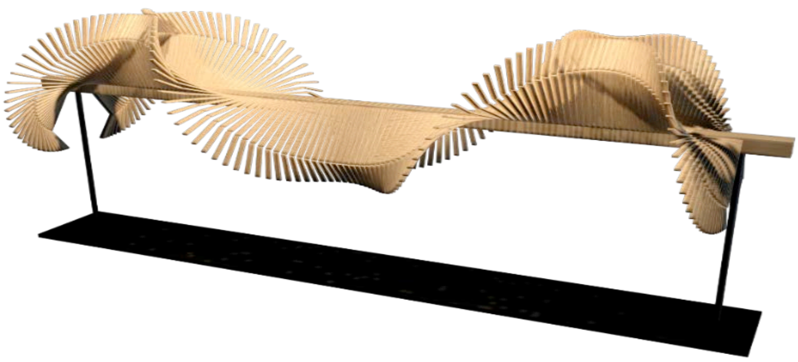

Fig. 2. A chronoform model inspired from Marey analysis of the flight of a seagull, Researcher.

Based on the previous concept we used the standard motion event unit of time to place arrays of hierarchal events in sequence one after the other, and we use time to compare how long events last to make time visually perceived relating our work more to Minkowski spacetime which combined the Euclidean space and time into a four-dimensional manifold where the spacetime interval between any two events is independent of the inertial frame of reference in which they are recorded.

As agreed also by the working definition offered by Adolf Grünbaum who defined time in the contemporary mathematical theory of continuity to physical processes, and he says time is a linear continuum of instants and is a distinguished one-dimensional sub-space of four-dimensional spacetime.

Now it is possible to warp or loop time or get back in time as if time is a linear entity after mapping the sequence of events using the proposed animation timed array model.

1. Background

1.1 BRIDGING THE GAP BETWEEN CHRONOPHOTOGRAPHY AND CHRONOFORM

"Time is nature's way to keep everything from happening all at once."
John Archibald Wheeler.

As Chronophotography was developed, at the end of the nineteenth century by Marey, Demenÿ and later Gilbreth and used as a tool for investigating motion. At the beginning of the twentieth century chronophotography's potential in other fields as in research for example was ignored as aspects of chronophotography were developed into cinema. Now, in what many call the post-cinematic era as expressed by Manovich (2001: p 296), artists and researchers are beginning to return to chronophotography to continue some of its unfinished stories. A chronophotograph contains information about interval, duration, speed and other derivatives of space and time. This information can and has been used to answer questions about spacetime perception. Movement is the physical act of traversing through space as performed by a body and is in contrast to the static nature of architecture. Bernard Tschumi stated, "There is no architecture without program, no architecture without movement." (Tschumi, 2000). Through his definition the measure of architecture lies in the relationship of the user and his experience of space, which emerges from the dynamic interaction of their activities. Marey's graphic method, with which he provides highly abstract representations of bodily movements to solve the problem of the tension between space and time, to principles of the quantum mechanics to result in what we called the spacetime model (Chronoform) where we explored the potentials of the synchronized arrays (decomposed frames of time) to define the geometrical shape of the model. Continuing this metaphor, the studies that Marey conducted in the early part of his career of decomposing movement, some of which we shall now describe, may be construed as devices for translating invisible phases of motion into the spatial code of graphic notation. His effort to refine graphic display of bodily movement, and eventually time itself, thoroughly dominated his work, including his innovative experiments with chronophotography. Marey experimented with several techniques of photographic representation the motion of natural phenomena like wind as well as human kinetics in various phases of motion. His aim was to decompose bodily motion into the smallest temporal and spatial segments possible within the limits set by representational techniques (Muybridge,1979). As Marey pointed out in this method of photographic analysis the two elements of movement, time and space, cannot be both estimated in a perfect manner. Knowledge of the positions the body occupies in space presumes that complete and distinct images are possessed; yet to have such images a relatively long temporal interval must be had between two successive photographs. But if it is the notion of time one desires to bring to perfection, the only way of doing so is to greatly augment the frequency of images, and this forces each of them to be reduced to lines (Marey, 1883). In other words, to make it possible to visualize time, he had to reduce photographs to diagrams. Photographs capture a plethora of detail that Marey believed was irrelevant to, and interfered with, the representation of time. Marey wanted to construct a pure geometry of time. The result was a pure, synchronized timed geometry of motion. Marey used chronophotography to decompose time into its 'elements'. In effect, he created an empirical geometry that could, he thought, show how continuous motion can be built up out of discontinuous series of fractional movements.

2. Application & methods

2.1 CREATING THE SPACETIME MODEL (CHRONOFORM):

Our spatiotemporal model simply fuses space and time into the single same interwoven continuum that involves gradual quantitative transitions without abrupt changes or discontinuities of the overall form in consistency to the Minkowski spacetime and developed as a descendant of chronophotography with the help of computer animation technology with representation of time contraction and dilation. It is the unfolding of series of moments visualizing the narrative of a certain event, picturing it through moments lined up in a controlled array defined by a geometrical path trajectory. The user stepping inside the chronoform will be defining his now moment by every step perceiving a new instance of the arrayed elements, where user motion will slow or speeds the motion of time depending on his velocity. Defining the geometry and length of trajectory path allowed the viewer to conceive it as an overall continuous spacetime model. And according to Einstein, whenever you do something to space, you also affect time. Physically you could walk through time as you walk through space with visual reading to its events where we freeze the events duration allowing the user to pass by them. As where Einstein explained that in order to travel through time you have to reach the light speed we on the contrary had frozen time in consecutive sections throughout the space to enable the user to walk through frozen time to achieve the same experience.

As a developed concept of Muybridge chronophotography, Chronophotography, is the photographic capture of movement over time. the chronoform is a model that enables the users to move backwards or forwards to observe different points in spacetime. The suggested name was derived from the Greek *chronos* (time) and the word (form) to suggest a form that tells a linear narrative based on its gradual quantitative transitions of modular structure synchronized by time unit. The new chronoform model is defined by the following parameters:

P: Trajectory path
T: Timing
N: Number of synchronized arrays
M: Motion typology

2.1.1 Trajectory path

The trajectory path is considered to be the main geometry spine of the chronoform timeline where it is the path that a moving object follows through space as a function of time. The object might be arrayed synchronized objects and hence will be the same path of the user inside the chronoform. In consistence with control theory which indicated that the trajectory path is a time-ordered set of states of a dynamical system, the trajectory path is the circulation line displaying a list of events in chronological order (See the fig. 3).

It is what defines the direction of the motion and creates a vector motion.

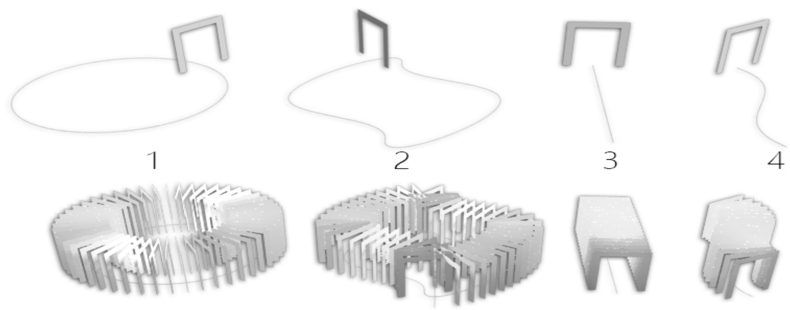

Fig. 3. Different trajectory paths resulting in different geometry of chronoforms, (Source: researcher).

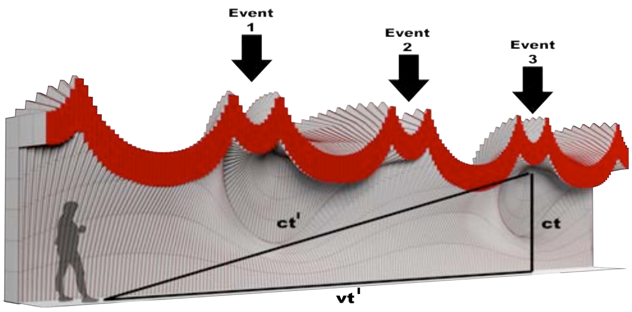

Fig. 4. Diagram showing the user inside the chronoform calculations, (Source: researcher).

2.1.2 Timing

Based on the theory of relativity, the user can move inside the chronoform timeline as a graphical representation of a period of time, on which important events are marked with the black heavy arrows.

Applying the same time dilation rule of chronoform and according to the Pythagoras equation

$(ct^i)^2 = (vt^i)^2 + (ct)^2$
$c^2(t^i)^2 = v^2(t^i)^2 + c^2t^2$
$(t^i)^2 = v^2/c^2\,(t^i)^2 + t^2$
$t^2 = (t^i)^2 - v^2/c^2\,(t^i)^2$
$t^2 = (t^i)^2\,(1-(v^2/c^2))$
$t = t^i \sqrt{1-(v^2/c^2)}$
$t^i = t / \sqrt{1-(v^2 / c^{2)}}$

Where:

- (t^i) is the time of the user inside the chronoform
- (t) is the time of the clock perceived by a stationary user outside the chronoform at the place of the event.
- (c) is the time of light where the event takes place by the perception of the user.
- (v) is the velocity of the user inside the chronoform

If we assumed that we had frozen the time due to the static chronoform that mapped the time frames.So this means that the user will be moving with a speed near to the speed of light

So practically when c = v, it means that time had frozen

$t^i = t / \sqrt{1-(v^2 / c^2)}$
$t^i = t / \sqrt{1- (v^2 / v^2)}$
$t^i = t / 0$
$t^i = \infty$

This is the same principles of time dilation theory but on the contrary of traveling the user with the speed of light we frozen the time to decrease the speed of c till it reaches the speed of user v.
Metaphorically the user can travel through time forward and backward.

2.1.3 Number of synchronized arrays

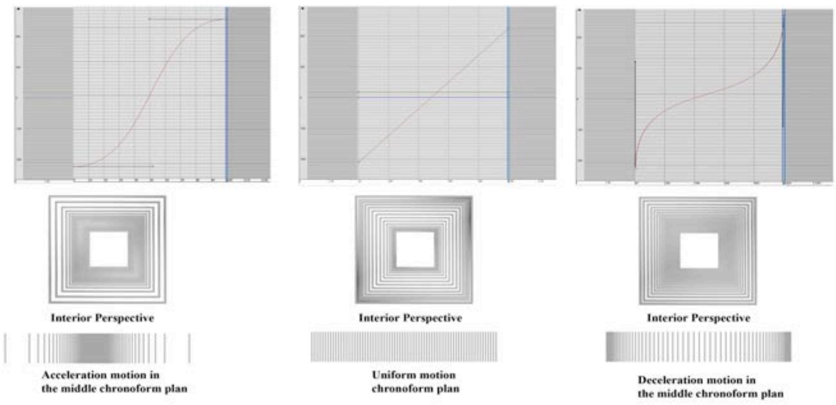

Fig. 5. Studies of Spatial and Temporal Sequence, (Source: researcher).

It is the array of a modular systematic range of a particular type of items in ordered arrangement with gradual transition and synchronized with a time measuring unit. The arrayed elements create the modular grid of the architectural form. Modular design is rooted deep in design theory and has been used by a number of architects for a long time. Transforming and growing according to the needs of the transition in spacetime is a key characteristic of modular nature of chronoform. The Modular nature of chronoform allowed it to grow by adding to or reducing in size by adding or removing the arrayed components. This can be done without altering larger portions of the chronoform. It can also undergo changes in functionality using the same process of adding or removing modular arrayed components.

2.2 APPLICATION

Greg Lynn indicated that architecture's relationship to time is typically posed in terms of the representation of motion (1999). The representation of time and motion in architecture has been a persistent theme throughout its history. The proposed application is a direct application of the previously discussed model. It is about engaging the time dilation and contraction technique of openings arrayed on timespace trajectory of sun path where the time contraction openings accelerating array will be performed in the morning and afternoon period and time dilation decelerating array on the noon period to maximize the sun rays entering at morning and afternoon period while minimize sun arrays from entering the space at noon. Time contraction here in this paper is considered to be the decrease in time of the openings array traveling on the same trajectory of sun path as measured relative to the observer. Whereas time dilation is achieved by a difference of elapsed time between two periods *(morning and afternoon)* as measured by users observing the openings arrayed at a non-uniform time pace.

2.2.1 Building the Chronoform:

Since the time of Vitruvius architects have described architectural space as a static construct. Computer animation nowadays provides an alternative description to the architectural form. Animation to analysis of space and form through time can have a significant role in the generation of architectural form resulting in a new structuring of the architectural design process. Since we defined the parameters controlling the geometry formation of the chronoform earlier in this paper, the same four parameters were taken into consideration while generating the suggested model. The key feature used in this technique is computer animation as referred by Greg Lynn (1999) the term virtual has recently been so debased that it often simply refers to the digital space of computer aided design. But while Lynn (1999) believed that Architecture has historically modeled time in terms of models of procession where architectural form is typically conceived as a modulating frame through which a mobile eye moves. The nature and complexity of the modulating frame has been the primary factor in discussions of temporal procession. In processional models of time, architecture is the immobile frame through which motion passes. We visualized time frames in our chronoform to draw the whole motion path in the user movement memory in consistency to Lynn's concept that processional time depends on static frames, formal time indexes time through the multiplication and sequencing of static frames. The following sequential steps were taken to build the chronoform:

2.2.2.1 (P): Trajectory path

Representing time as linear entity offers a way to describe spatial organizations through the objects arrayed changing profile and trajectory. Broken into fragments of arrayed objects along trajectories that might have meaning lines may act as descriptive linguistic elements. The trajectory path was generated from the sun path extracted with the help of the software algorithm after defining date by first of June 2016 and the geographic location of Zurich. However, the concept of the chronoform is designed to be a generic model that could be applied in anywhere else but for the particularities of the experiment we had to specify a date and geographical location

2.2.2.2 (T): Timing

Computer animation now days gives us the privilege to control time visually using motion graphs which enables us to accelerate or decelerate motion as required. That will result in a narrow rhythmic array or wide rhythmic array as will be shown later in this research.

2.2.2.3 (N): Number of synchronized arrays

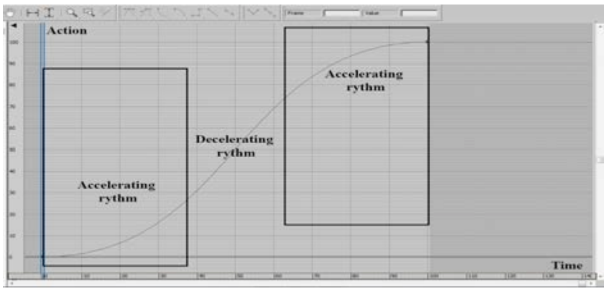

Fig. 6. Accelerating and decelerating action vs. time graph, (Source: researcher).

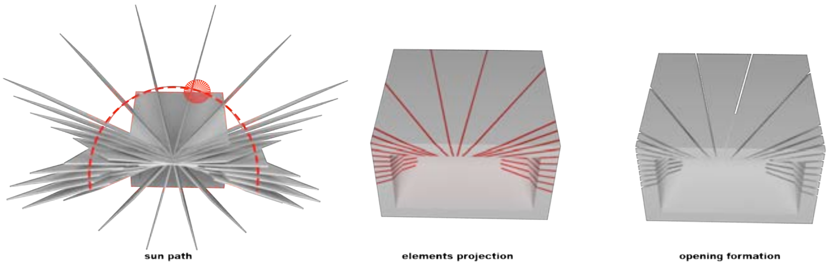

Fig. 7. Final process of arraying the openings along sun path trajectory, (Source: researcher).

Depending on the last principle of time control through the visual graphs the continuity of motion is divided and proportioned based on the number of arrays that is to be generated. Fig.(6)

3. Results and reflection

This paper is considered to be the meeting ground between art and science as the original definition of architecture itself claimed. Art represented as a developed descendant of chronophotography using latest computer animation techniques and science in rethinking the application of spacetime in the architecture. Chronoform is a fusion of time and space unfolding a series of decomposed moments visualizing a space narrative in a vectorial linear continuum.

4. Conclusion

We explored the potentials of spacetime through a scientific and artistic perspective using computer animation. Animation in architecture is traditionally used as post-design exercise in service to the representation and visualization of a project. The role of this paper was to rethink animation to explore new possibilities to achieve sustainability using the animation techniques Although a large amount of work has been done in space time modeling by physicts and mathematicians, many issues are still open and deserve for architects, further research needs to be conducted, especially in the following areas:

4.1 SUSTAINABLE ARCHITECTURE APPLICATIONS
How can the chronoform inform a design problem in response to wind and sun movement pattern to create passive design using Kinetic architecture.

4.2 INTERFACE BETWEEN ARCHITECTURE AND QUANTUM MECHANICS
Studying the relationship between quantum mechanics theories like Lorenz attractor for example and user behavior inside the chronoform to observe its impact on sustainable design.

4.2 DIGITAL FABRICATION AND PARAMETRIC DESIGN
Parametric design has a great potential in liking modern physics and architecture form finding and testing these theories as a generative medium for design to visualize phenomena like gravity and wind forces.

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