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Space and Time in HyTime

by Michel Biezunski

Introduction

HyTime is a brand new ISO standard introducing a language for structuring Hypermedia and Time-based documents. It is based on SGML and it features a description, not only of the logical structure of textual documents, but also of multimedia objects that must be located both in space and in time. These objects may be fixed as well as moving.

There is an emphasis today to be able to model multi- and hypermedia applications that are independent of any systems, at least for the logical structure if not for its actual data content (video, music and formatted text).

This paper is an attempt to browse the HyTime specifications related to space and time. One of the simplest ways to understand a new concept is to try to relate it to something already understood. Herein, I try to compare it to another theory involving space and time, Einstein's physical space-time theory of relativity. The object of physics, generally speaking, is to describe reality by attempting to make it fit a mathematical description. This opens the possibility of applying the power of mathematical logic to phenomena that exist in the real world, and conducting experiments to match the model with the reality. In paralleling that with hypermedia, it is possible to consider actual hyperdocuments as real elements, on which experiments can be conducted. This opens the possibility of applying generic algorithms and large-scope processing to complex hyperdocuments, loaded with links, spatial alignments and temporal synchronizations.

The parallel that is introduced in this article should be considered more as a metaphor than as a real attempt for relating the HyTime standard with a scientific theory, or even to give Hytime a scientific background. Furthermore, this correlation will eventually prove limited, but I hope that it will help clarify the basic concepts, as far as space and time are concerned.

The readers who might be afraid of this corollary should remember that the effort required to understand HyTime can compare quite closely with the effort that was necessary several years ago—and is still for some users—to introduce oneself into the SGML universe. It has not been natural to abandon the traditional vision of text, based on its visual appearance—typography and layout—to reveal a sort of "hidden" logical structure.

see page 2

SGML is Hot at Seybold '92

by Dale Waldt

The 1992 Seybold Seminar held in San Francisco's Moscone Center, September 22-25, again proved to be quite an extravaganza. Thousands of people and hundreds of vendors got together to discuss the latest in electronic publishing systems and the issues faced today by publishers of print and electronic media.

The focus of the conference is on a broad theme of devices, systems, and technology supporting the creation and maintenance of documents in various delivery media. Although, in the past, Seybold has focused on the software and hardware applications used to produced documents, with considerable emphasis on desktop publishing and interactive professional composition systems, this Seybold Conference had a more strategic feel to it. Much of the discussion focused on the theme of the evolving information publishing process. In the seventies and eighties developments usually were related to increased power of processors, and the

see page 10

in this issue...

Diving into HyTime requires this same kind of effort in order to look beyond the actual multimedia or hypermedia documents and to be able to discover—and to express in a generic way—the spatial and temporal relationships that must remain unchanged when one wants to exchange documents between different and heterogeneous environments. Indeed, a definition as basic as the demarcation between what is application-specific and what is generic to the document is not yet clear in all cases for hyperdocuments. As one delves into HyTime, one must raise the question about space and time relationships.

If one examines the way Einstein's theory was first popularized, the question of the relativity of time was a critical one. The introduction of the concept of "relative time" (*i.e.*, a time that varies with the observer) raised many questions among people used to considering time as an absolute and linear flow. People used to say when the theory of relativity was first formulated that only ten people in the world could understand it. Is this indeed not true with HyTime? As the space-time model in physics is now universally accepted, so will be HyTime in the next few years.

Time is Central in HyTime

HyTime begins at the point where time-based representation is added to an SGML-like structure. HyTime provides mechanisms for specifying interconnections (hyperlinks) within and between documents, and for scheduling multimedia information in time and space. This paper focuses on the second topics, even if the hyperlink module exerts an effect on space-time representations.

In HyTime, the definition of space is derived from time. The importance of time to HyTime is reflected in the name of the standard. Time in HyTime takes its origin from SMDL (Standard Music Description Language), which is now at the stage of a draft international standard. SMDL's basic idea is to define musical structures using SGML. Musical notation is the only consistent system in which time intervals can be represented and trigger dependent operational procedures as musical scores represent notes to be played. A score is a two-dimensional diagram, in which the horizontal axis denotes time duration, while the vertical axis denotes pitch. One could consider the inter-relationship of many instruments in a two-dimensional system to, in fact, constitute a third dimension. A number of attributes can be added that correspond to notations for interpretations or renditions, such as changes in speed, *etc.* A score is a mapping of time in space. But it is important to realize that in this system, space is only a display of time. Scores do not contain, in themselves, spatial relationships. Today, SMDL is considered an application of HyTime, and will be edited to be consistent with the features that have been developed in the hypermedia/time-based documents' general perspective. To summarize, time in HyTime takes its origin from music.

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The Relation Between Space and Time

HyTime does not differentiate formally between space and time. Space is described exactly like time. This is different from physics, where time is handled in a way that can not be equated with space: as an imaginary number is introduced on the time axis. Although space and time are interconnected, they are not on the same level.

But the definition of space can vary dramatically from one point to another, or from one moment to the next. Therefore in HyTime, there is not one unique space that serves as the stage on which a play is presented, but each location or event contains its own space definition, which may or may not be the same as its neighboring space.

In physics, space is the same everywhere. It is described by a unique geometry. To illustrate, classical space is a space described by Euclid's postulates, in which there is one system of coordinates. In the Cartesian geometry of space, transformation laws exist that allow passage from one system of coordinates to another. The simplest transformation is a translation. This means that somebody in the back of a room will be able to get the same description of a spatial phenomenon as someone who is located near the front. His perceptions of the space will be shifted by the distance between the two positions. The fact that the distance between two points is always the same, regardless of the locations of two different observers, defines what is called the *metrics of space.*

Usual 3-dimensional Cartesian space has one set of metrics valid everywhere. This is also the case for the 4-dimensional space-time coordinate system introduced in the special theory of relativity, which is called a Minkowskian metrics. In other words, there is an abstract property that characterizes the space or space-time. Special relativity is limited to relative uniform motion, such as two observers who move relatively to each other with a constant velocity. In general relativity, where all relative movements are acceptable, however, the previous space-time is only locally valid. The space-time between different events is curved and obeys another geometry, which is not cartesian, but Riemannian. Each event has an associated "flat space", and between local flat spaces, space is curved. This is our situation, as inhabitants of Earth: we live on a curved space but we behave as if locally we are on flat space, characterized by parallel vertical and horizontal lines.

This idea introduces the first important difference between the two models. Physics defines a global space, which can be described by a mathematical theory, while HyTime defines no space between the local spaces. Therefore HyTime's global space is empty and its local spaces can be entirely different one from another.

In HyTime, there are different kinds of objects called "space": The name space, which can also be labeled "SGML space." Space in this sense is composed of identifiable elements, or entities, that can be referenced with an unique identifier (ID and IDREF mechanism). All other spaces in HyTime are "time-like," *i.e.*, are describable provided one has a coordinate system called a "finite coordinate space" (FCS). Time referencing is an example of such an FCS. FCSs can of course be used as well to represent spatial measurements, such as the relative location of an object on an axis, a byte in a file, or a word in a sentence, *etc.*

Two Types of Time

In physics, as in HyTime, time is divided into two different categories that seem to be similar but are in fact different.

In HyTime there are two types of time: virtual and real. Virtual time is a regular quantified time, such as the one that is defined on musical scores. Real time is the actual time elapsed when a work is performed. There is usually a variance between virtual time and real time. "*Accelerandi*" and "*decelerandi*" are subject to interpretation by each solo musician or conductor. Any two different performances of the same work never have the same duration.

In relativistic physics, there are also two types of times: one that elapses within the system, called proper-time, and another that is measured outside the system, by an observer travelling at a relative speed towards that system, called observed time. The observed time measured from outside the system is always longer than the proper-time.

As there exists in both systems a variance between virtual (proper) time and real (observed) time, one might conclude that they are similar. But in the Special Theory of Relativity, as the relative speed is uniform, there is a quantitative mathematical relationship between the proper and observed time. However, in HyTime the only relationship between real and virtual time is based on the ever changing rendition.

Is Time Finite or Infinite?

Time is measured on a single axis, beginning at an origin. In physics, the time axis is infinite and time is continuous. There exists a standard unit of time (the second in the SI system), which is defined as a certain ratio of the vibration of an atom of cesium. In HyTime, the second is also the basic unit. It is called the "standard measurement unit" of time. In HyTime, the time axis is finite. This is true because the length of the axis corresponds to the duration of the musical piece or of the video sequence in a hyperdocument. Also the axis is not a continuum, but a series of fixed intervals, called "granules", defined as system independent units. For example, the granules can correspond to the frequency of images in a movie, or to the beat of a musical work. The fact that the end is defined as well as the beginning makes it possible to count backwards from the end. This difference is more important than it seems, because the mathematical foundations of a continuum is completely different from its counterpart in a discrete set.

From this point, it is impossible to appreciate direct parallels between the two systems. Physics does not pretend to define the world as it is, but to make it fit into a "simple" mathematical description. However, HyTime tries to remain as close as possible to the actual hyperdocument. It is a descriptive language, not a formalized theory. Hyperdocuments are real, but their realness is somewhat different from that of the universe. This makes HyTime easier to understand for people familiar with the creation and management of hyper- and multimedia documents, but renders it more difficult to those who are looking for general algorithms to handle hyperdocuments, such as software developers. We can realize the same difficulty in SGML. SGML allows the description of very complex document structures, while being difficult to implement with simple computer algorithms. Nonetheless, in spite of its power and complexity, it is possible to create SGML-tools. Therefore one can reasonably expect that HyTime tools would also be developed. Indeed, this is already the case.

The difference in the level of modelization is a general philosophical problem raised in the relation between mathematics and computer science. Mathematics is elegant and efficient, but does not always easily fit into the computer domain. Inversely, computer science is operational, but does not always fit into a beautiful and simple theory, even if the logic on which it is based is rooted in simple mathematics. There are of course intersections, like in the Graph theory.

Quanta versus Continuum

The fact that the axis of time is divided into quanta introduces another major variation from the relativistic description, based on continuous time. Therefore, in order to take into account the quantification, we have to shift to the quantum theory of physics. There, we find that major difficulties arise, as one of the unsolved problems of contemporary physics is the integration into the same universal theory, of both the theory of relativity and quantum theory, which are based on incompatible — or hardly compatible — conceptions of space and time. During the last decade, this problem has been at the heart of the so-called theories of unification. Therefore, the HyTime description in terms of a physical model would immediately encounter the same types of problems as in contemporary physics. This is not absolutely impossible, but will require working at the highest levels of current theoretical physics. The initial attempt to try to map HyTime into a space-time theory of physics has proven to be much more difficult than first thought.

Measuring a Location

The mechanism used for measuring a location in a Cartesian coordinate space system is quite simple. Taking the example of a one-dimensional space (a line), one sees that there is an origin, and each point on the line can be marked by an unique number expressing its distance from the origin in terms of a multiple of the basic unit. If one wishes to describe a segment, one has only to describe its two end points.

HyTime uses a slightly different technique, which is similar. The first marker expresses the origin of the "object", while the second expresses the number of "quanta" that equals the length of the object (called the "object dimension"). HyTime has an additional feature: it can also specify the position of an object by a negative number, which is an instruction to count from the end of the range, rather than the beginning. Therefore two linear coordinates can define both a transformation (translation) and a length. This method of identifying positions is quite different from the usual vectorial methods describing points in a simple space structure, as is the case in a Cartesian geometrical space.

It is apparent that the important feature in HyTime is not a simple mathematical description of space, but an ability to locate precisely an object, regardless of the mathematical transformations one uses. For this reason, the "addressing mechanism," essential in HyTime, can not be mapped to a simple spatial geometry.

Ordering: the Scheduling Module

Objects are placed into "events" that can be aligned or synchronized on a schedule. This is like placing paintings in frames that are aligned on walls of museums. The order of the objects in a hyperdocument is significant. The purpose of the scheduling module is to regulate this feature. As everything in HyTime, the scheduling module is defined by time-based sequencing (but space is considered equivalent).

Events are ordered on "event schedules". One particular axis is called a calendar, and it is measured by means of an absolute date and time. Events can begin at specific dates and times. A date is the day of the year, while the time is the hour of the day. These two specifications, seen in an absolute physical time axis, merge into one, because the hour, minute and second measurements can be added to the number of days from a referenced time origin. Assigning a location to an event at a particular value of date and time becomes the same thing as locating an item at a structured level in HyTime; for example: "January 12th, 1992; 10:00 a.m." is formally equivalent to: "3rd sentence; 4th word".

What HyTime calls the "absolute time" refers to the "Universal Time Coordinate" (UTC) format. The concepts of "time zones" are used to refer to shifts in UTC values, another difference from absolute time in physics. Absolute time expresses the fact that time durations are the same for any observer, regardless of his state of motion. With "relative time", time duration depends on movements of the observer relative to the system he is observing.

In relativistic physics, there are also events and absolute time. These do not equate to HyTime definitions. An event is no more than a point in space-time. In this context there can be no notion of "size" or "extent" of an event. Absolute time means that time measured by an observer is always the same regardless of its relative speed to the observed system. But relativity shows that absolute time does not exist, as the time measured depends on the relative speed of the observer towards the observed system.

The rendition module of HyTime allows for "event projection" and "object modification".

The projection feature deals with the transformation of the position and extent of events during a rendition. In other words, converting the coordinates of an event (position and extent) from one coordinate system into another, allowing us to call HyTime a theory of relativity.

Even though Einstein created the special theory of relativity as a model to express the synchronization of clocks measuring events located in different frames of reference, it was later shown that his theory could be described by a space-time model. Further development allowed a mathematical expression of his work in terms of the group theory, which rendered the model much simpler, from a mathematical viewpoint.

If we could develop a similar theory for HyTime, it would aid software developers seeking powerful algorithms enabling them to process any kind of HyTime document. Unfortunately, for reasons stated above, because space in HyTime is discrete, finite, and "plural", it is not possible at this stage to present a viable mathematical structure hidden within HyTime.

Conclusion

HyTime was conceived to deal with the encoding of complex objects included in hyperdocuments. This does not mean that a structure will not emerge one day. The fact that we do not currently possess a mathematical description of HyTime does not prevent the practical application of its concepts. Physicists often apply operational procedures without relating them to a complete mathematical system. Occasionally, these complex mathematical systems are discovered decades later. This was the case for example with quantum physics, one of the most succesful systems of all times. The fact that physicists did not agree for a long time on its conceptual foundations was not an obstacle for major breakthroughs, *e.g.*, semi-conductors and electronics.

Though more work could be done on the conceptual foundations of HyTime to clarify its main concepts, it is unlikely that further work would significantly change the process of exchanging multimedia and hyperdocuments. Even though HyTime can be considered as an exciting area of ongoing scientific developments, it is already operational.

The topic of this paper may seem far from the concerns of document architecture developers. In part, this is true, but a comparison between two approaches, whose methods and objectives are different, as was shown, has provided insights into the innovative power contained in HyTime. The level of analysis required invites new insights from document architects who are searching for a generic description of space- and time-related events that occur in multimedia documents. It is essential to understand than to reach this description, one has to be creative and must question the very nature of hyperdocuments themselves. This research requires further conceptual effort. Many people tend to discard it as an purely intellectual construct. Can the same case not be made for multimedia and hypermedia publishing as well? As the level of complexity has increased, so has the requirement for analysis. HyTime opens the door to hypermedia exchange. It is an enabling standard, which does not intend to emprison actual hyperdocuments in a set of pre-formatted templates. The price to pay to access and to maximize their use is to take into account HyTime's radical novelty. </>

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