MSc Program "Building Science & Technology"

Title: 4D BUILDING MODEL

A conceptual system of the time dimension in the building's life

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Affidavit

I, **Martha Vaizidou** hereby declare

1. That I am the sole author of the present Master Thesis, "4D Building Model ", 57 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and

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ABSTRACT

The research topic"4D Building model: a conceptual system of the dimension of time in building's life" is the concept of a web-based interface of a databank that stores and visualizes information of the building's life process. It is an organization data model that brings together the serial steps of the lifetime of a building, following the design, construction and its operation time. Observing the aforementioned process as an entity, the model aims at approaching the passage of time during it, depicting the temporal relations between past, present and future steps. Visualized stored information depict the becoming of the building in time. It attempts to approach the idea of 4D architecture and explore how the dimension of time is incorporated into the model. It studies the role of information in architecture and building process observing it changing in time. The aim of this research project is to define the frame of a conceptual information system, that could develop in a plug-in by an existing design software. The model will support the design and building procedure operating as the building memory, and reporting its behaviour during its life time. In its data base, there will be reported the serial and parallel actions during the design and construction phase and additionally the reports of the monitoring evaluating system during its operational time. The final model should provide several possibilities of decision making, regarding the energy consumption, the materials life span, the costs, the participation of different firms and components.

Keywords: time, dimension, information, temporal changes, virtual, actual and real object, building's life

ACKNOWLEDGMENT

My studies in the graduate program Building Science and Technology were a confrontation between my theoretical background and a more rational scientific approach of architecture. The result is an interesting mixture of ideas and concepts that build a dialectic relation in my mind.

My studies in the graduate program Building Science and Technology during the years 2004-2006, were granted by the Empirikion Foundation [1]in Athens, Greece

After a long trip I reached finally my private Ithaca, I accomplished the Master Thesis.

During this trip

O.Univ.Prof. Dipl.-Ing. Dr.phil. Georg Franck supported me consistently to open my horizon, to explore new ideas and expand the limits of my ability of thinking

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1 INTRODUCTION

1.1 Research question

The architectural object has a life itinerary that is complex and multifarious similar to the one of a living organism. In the beginning the conceptual idea is conceived through the design procedure, realized in the construction phase according to the design guidelines and begins its life with the capabilities that its construction provides, reacting to external and internal inputs of the natural and human environment[1], undergoing several reparations and restorations until it collapses and dies. This itinerary is not an alignment of discrete actions. It is a non linear folding[2] of several phases where the former leads to the next one either through continuous steps and overlaps or otherwise loops, deflectors and repetitions.

The isolation of every phase in the buildings life leads often to lost information, waste of time due to inefficient link of information or inability to plan future steps. The idea of following continuously the building process and observing its life as an entity brings new opportunities of redefining the relation architect-user to the building and leads to a new horizon of views and actions during the whole life span of it.

[1] The interaction of the building with the human and natural environment is defined by Ardeshir Madhavi as building *performance*. The building *performs*, namely it reacts in changes. There is the ecological, the aesthetical and the socio-cultural performance.[15]

[2] The word folding is referring to the notion of *fold*, analyzed by Gilles Deleuze in his work *The fold, Leibniz and the Baroque*. In the current research article there are used the interpretations of the delezeuian *folding,* by Vyzoviti, and Gourdoukis [8][24] Folding is the description of a continuous process of mental or spatial relations, where the outside intertwines with the inside. The fold comes up when the outside *wraps* in the inside, creating in it a new *situation* that bears a possible action. In this way there is a distortion of the continuous structure, a dislocation that causes new situations and actions. In this dialectic relation between the outside and the inside the limits are indistinguishable and the outside becomes a continuous line that connects the different *event.*

1.2 The dimension of time in a building model

The building is not a static entity. From the paper status and during its life time it undergoes transformations, that happen in a shorter or longer time span. In every step of this procedure, either designing the building, or constructing it or living in it, someone has to recall information from the recent or later past, in order to build up the experience of the present, to compare and replace or correct decisions and to anticipate the future, to plan the next steps, considering the future changes and studying several possibilities.

The attempt to capture every moment in the ongoing process of designing[3] and building and to describe the passage from one step to the other expresses the need to approach this process as time changing. During this process every moment-step (present) partakes of the previous moments (past) and of the next moments (future) in which it tends to embody itself, defining the limits and the nascent dynamism of the steps coming. Every step of the building's life is considered to be a discrete phase where the form of the building is impregnated with elements and realized choices from former steps and tends to prolong its essence to future steps and to associate the present form with different possible actions and transformations in the future.

Consequently, the steps in a process are melting in one another so that someone can not easily distinguish the limits between them. Considering that the design and building process consist of successive states that develop in time, between state A and state B, for example the design status and the building permission plans or the several construction states , someone has to follow the in-between steps, this becoming of the latter to the next and focus on the details of this movement. There is of course the question how deep in detail of successive steps someone can reach, but the scale is probably defined according to the needs and interest of the investigation and research. Observing the whole and going deep in detail are not two separate conditions. Like the successive moments-steps of o process that melt into each other, there is also dialectic ongoing of up and down in scale of detail along this succession. Accordingly, a process in time is not only observed as a horizontal but also as a vertical development in time.

[3] Michael Dürfeld develops a web-based interface where the design progress is described in every step, in order to follow the changes and transformations of the design building object in the passage of time [3]

1.3 Motivation

The proposed concept of a building model concentrates at:

- The cognitive map of the temporal relation of changes in the past, present and future of the building development
- Depicting the dialectic relation between design stages and realization of the building project
- Observing, in whole process, the horizontal relations of successive moments and the vertical relations of detailed view in a specific moment.

It aims at saving and visualizing the life span of a building, from its "birth to its death", depicting the crucial steps in its development. Additionally, the model aims at storing the different versions of the design process, in order to help the designer recall easily the changes that are done in the past and may redefine also the future result.

As the contemporary architectural tasks become more complex and the numbers of participants such as design components and firms is increased, there is the need of an organizational model of every partial impact of information that structures the global. The user can study the relations between past and future, design and realization.

1.4 Innovation

The research done in this topic until now, concentrates mostly in a specific part of the building process, such as the construction phase, for example the research done by M. Fischer and Mc Kinney in CIFE, Stanford University [4], where the 4Dmodel links the 3D visualization with schedule and construction activities. Nevertheless, they do not cover the complete itinerary of the architectural object from its design phase and also during its life.

The present paper, aims at studying and presenting the whole life of a building, as a living organism, that is born, lives and dies. This will help someone to identify the relation between designing and planning with the life of the realized object.

Additionally, it aims to develop the concept of a plug-in application in existing software for 3D architectural design that will support the design decisions and the overall control of the building process.

1.5 Project tasks

- Development of the concept of an information structure system with data concerning the building
- Development of the concept of visualizing the stored information
- Development of the interface of the model
- Animating the life time building process through the example of a realized project

2 THEORETICAL APPROACH: the dimension of time

The subject of time and time flow concerns the human culture from the earlier stage of its existence. In every historical period, mankind tries to identify and interpret the notion of time according to its own knowledge and mental achievements, its cultural heritage and the contemporary tools and media. From the ancient times until now, each knowledge based field as for example mathematics, physics, astronomy, philosophy and theosophy explores the characteristics of temporal processes from different point of views and with different criteria of importance. Clockwork and stars calculator methods for observing and studying the movements of the planets and the universe's time flow were technologically developed in mathematics and astronomical theory and praxis thousand years ago in Ancient Greece[4]. Understanding time as a tool of experience[5] , the approach of this subject differs in every scientific or philosophical field because there are different phenomena chosen to be studied and analyzed and consequently they conclude in different truths about time.

Though, every knowledge based field and cultural spirit developed by human society in history connects time with the notion of change.

Approaching the question of how time passes, G. Franck distinguishes two kinds of change. Real and temporal change. [6] The real change refers to states that differ in date, function and structure. Temporal change is the mutation of a physical state in time being once future, afterwards present and passing finally in the past, undergoing changes in function and structure. For real change there is no interest in time flow through future, present, past. It is an observation from an eye outside the physical state that is described. Temporal change is an observation from an eye being inside the physical state, personified, and running in time with it. Real change is a static observation, temporal is change within change.

As long as the interpretation of time flow varies among several knowledge based fields, also the interpretation of change differs.

[4] Recently, in a research publication there was information about the wheel work found in the wrack near Antikythira in Greece and studied by British academic researchers. This mechanism was developed under the theories of astronomers and mathematicians and seems to be a high technological achievement of that period. (www.antikythira - mechanism.gr)

[5] "*Time is a fundamental dimension of experience*",writes in his article G.Franck entitled *Time,Actuality,Novetly and History*, Published in: Life and Motion of Socio-Economic Units, edited by Andrew U.Frank, Jonathan Raper and Jean-Paul Cheylan, London: Taylor&Francis,pp. 111-23

In physics, for example, according to G Franck, time is considered to be a counting tool to describe real changes. [6] In this case, time is parametrical, t and –t, reversible and without direction. In physics, someone wants to study the material change of a physical phenomenon from state t1 to state t2. The in-between moments that flow in a continuous way and describe this becoming are not of an interest. There is no passage of time, there is no past or future and consequently there is no temporal change. There is a universal now status, as seen from someone being outside of this block of states, likes the Gods eye.

In the article *How time passes*, On conceiving time as a process, G. Franck explains that relativity theory introduces a new prism of principles for space-time, where motion is always relative to the observers point in space and thus it denies a universal eye, or a universal now. With the relativity theory real change and temporal change- an event that has been future is now present and belongs later to the past- are distinguished. According to this, the universe is seen as a block of states where only processes of real change occur. Temporal change is an epiphenomenon, an additional phenomenon that helps the overall understanding of universal things functioning that is not accepted as real. These two kinds of change are orthogonal to each other. (Figure 1) They do not mix, but they build an orthogonal system of reference, like the x and y orthogonal axial system. Consequently, the dimension of time functions as a 4th spatial dimension of the universe. It calculates distances in space.

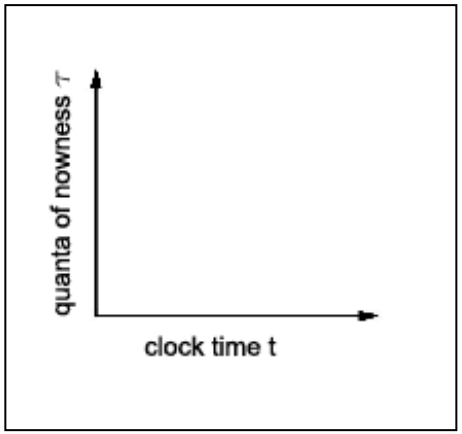


Figure 1, orthogonal system of clock time t / duration τ

The phenomenon of entropy is an example of a directed time process. There is also no passage of time through future, present and past but there is a directed time mutation, in contrast to the rest of physical phenomena.

2.1 Temporal change: the present moment travels in time

While in Physics time is a static parameter of the 4th dimensional space or a directed development in case of phenomena like entropy, in Socio-Economy, in Architecture and Philosophy time is approached as the dimension of temporal change and flow.

Despite the fact that theoretically real and temporal changes are orthogonal to each other, in the praxis, human experience them both indistinguishable. Observing the semiology of the words "tomorrow", "yesterday", "in one hour", "five years ago" [7] one reaches the conclusion that the observer, the human conscious is always placing itself in the now. Everything is related to this now, that human experience as mental presence. Consequently, placing ourselves in the now, as architects or users, we perceive the passage of time by experiencing different actions, events that have been once future, they are presence at the moment of experience and pass to the past, reported in our memory. We understand time flow either because of our own change or observing the change of materialistic elements in the outer space[6].

[6] Under the terminology ecological potency and ecological valency, A.Mahdavi defines on the one hand the changes and transformations

Following human experience of time flow, there is the effort to establish also an objective theoretical plateau in order to approach the experience of present, of now, and to reconnect real and temporal change.

2.1.1 Now: the present moment as time slice or *sensori-motor*

In the aforementioned article, G.Franck suggests to narrow down the observers eye into a time slice (hyper surface) that represents the present moment. The block universe is divided in time slices that describe every discrete state and one of them is the slice of actualization, of now. The slice of the now rolls through the different states and travels in time. Along this passage, the states left behind belong to the past and the states coming belong to the future.

In addition to the former approach, Bergson [1] binds past present and future with a continuous net based on the present perception, on that we call "my present". He names the physical state that describes "my present", sensori-motor. According to his thesis, immediate past lives in us as sensations and immediate future is action and movement that our body is going to do in space in the next moments. Present is sensations and movements together, a sensori-motor. Since present forms an undivided whole, the movement must be linked with sensation, must prolong it in action, because my present consists in the consciousness I have of my body so my body experiences sensations and executes movements.

One could say that sensory motor is the personification of the picture of the time slice traveling in time. Against this assumption though, speaks the fact that G.Franck builds up his traveling hyper surface, while he introduces an objective now ness. He suggest that if now is objective then τ expresses that it is always now, whether or not a conscious being is in the state of mental present.

According to the approach of G.Franck, about the essence of present, narrowing down the observer point of view means slicing time in minimum intervals of clock time Δt (Eigentimes). The dimension t measures the distance traveled by the now, but not the time used for this traveling. Therefore, he introduces a second dimension, the minimum quanta of chronon τ. Chronon τ represents the time that the now needs to travel form one state to the other. The dimensionality of time is crucial in perceiving the passage of time. The trajectory that the time slice follows represents temporal change and marks the cognitive map of the present. (Figure 2,Figure 3)

that human being experience in relation to the built and natural environment (potency) and on the other hand the changes that the built and natural environment undergo in relation to the human influence (valency) in a specific point in time. [15]

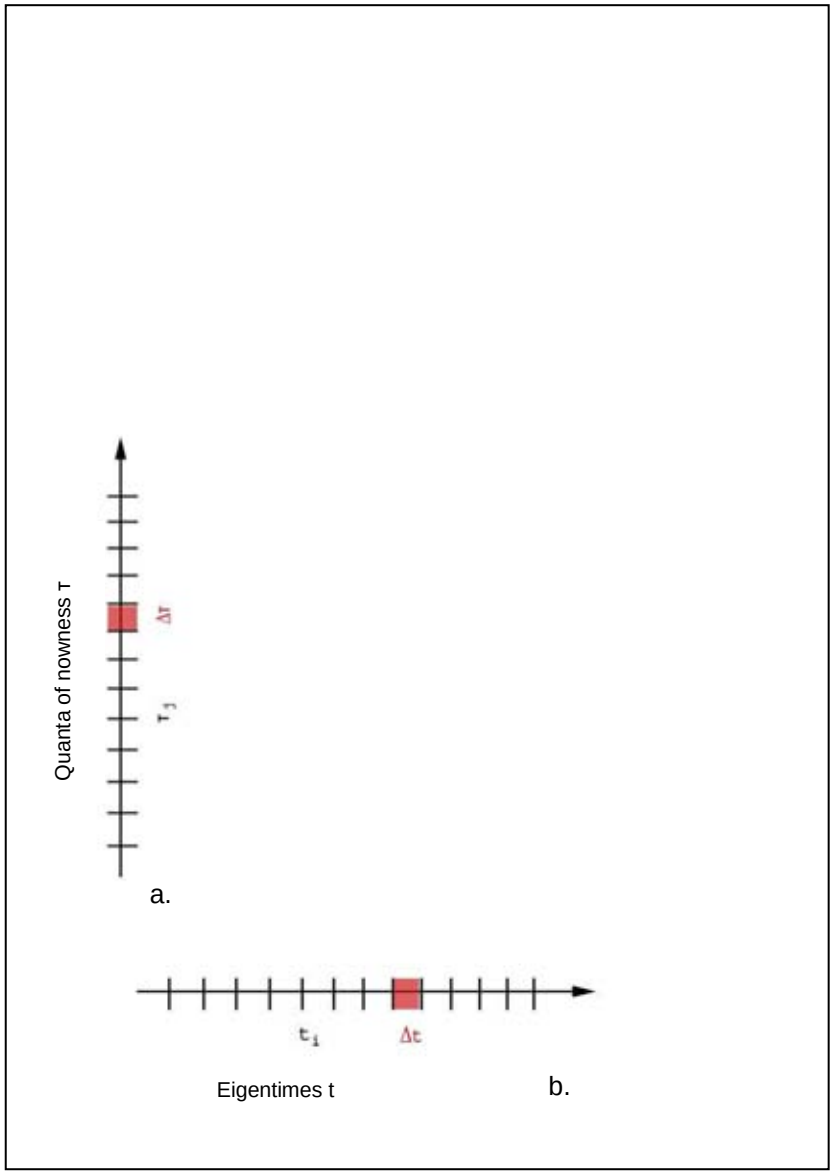


Figure 3 a. b, quanta Δ τ and eigentimes Δt, based on [6], pp.4, Figure 1a

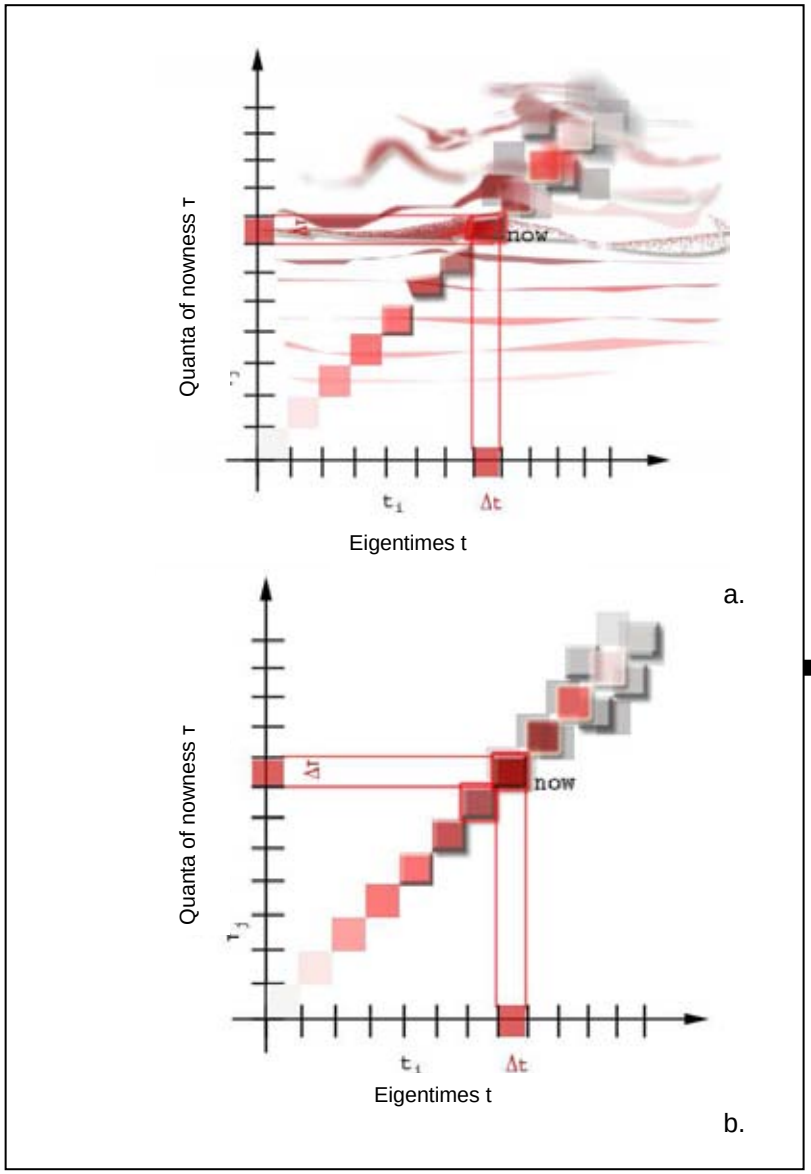


Figure 2 a. b, the traveling of the now, based on [6], pp.4, Figure 1a

2.2 Temporal relations of past, present and future

2.2.1 The A, B and C series by Mc Taggart

The approach of Mc Taggart [16] about the unreality of time will help to analyze the nature of the time sections Δt and $\Delta \tau$ ordered along the time axis of real and temporal change.

Mc Taggart proposed that time could be described by three series, the A series, the B series and the C series.
He defined these as follows:

The A Series: ".The series of positions running from the far past through the near past to the present, and then from the present to the near future and the far future." [16] Mc Taggart further declared that "the distinctions of past, present and future are essential to time and that, if the distinctions are never true of reality, then no reality is in time." (Mc Taggart) [7]He considered the A series to be 'temporal', a true time series because it embodies these distinctions and embodies change.

The B series: "The series of positions which runs from earlier to later." (Mc Taggart) [8]The B series is temporal in that it embodies direction of change. However, Mc Taggart argues that the B series on its own does not embody change.

The C Series: ".This other series -- let us call it the C series -- is not temporal, for it involves no change, but only an order. Events have an order. They are, let us say, in the order M, N, O, P. And they are therefore not in the order M, O, N, P, or O, N, M, P, or in any other possible order. But that they have this order no more implies that there is any change than the order of the letters of
the alphabet…" According to Mc Taggart the C series is not temporal because it is fixed forever.[9]
Consequently, Mc Taggart defines two Series where events have fixed positions and no change occurs and the A Series which is instable and continuously changed. About the C Series he argues that events have such a stable position like the letters in an alphabet. Change and additionally the passage of time is occurred in the A Series where "It began by being a future event. It became every moment an event in the nearer future. At last it was present. Then it became past, and will always remain so, though every moment it becomes further and further past." (Figure 4)

The thesis of Mc Taggart is about the dimensionality of time. He declares that in order to describe the passage of time someone needs more than one dimension. He introduces three time series so that he can divide time into parameters. Theses parameters are the tools to control and explain changes. Similar to the thesis of G. Franck, he distinguishes two kinds of dimension embodied in the ontology of time. One is objective, regular and determines distances in space-time (clock time, *Eigentimes* t for G. Franck), and the other is an objective tool to describe the subjective human perception of the continuous passage of time from future moments to present ones and afterwards to past memories.

[7] The text is taken from the philosophical article about Mc Taggart, *The Unreality of Time*, Wikipedia, The free Encyclopedia, Philosophical article, http://en.wikipedia.org/wiki/The_Unreality_of_Time, (21 March 2007)
[8] The text is taken from the philosophical article about Mc Taggart, *The Unreality of Time*, Wikipedia, The free Encyclopedia, Philosophical article, http://en.wikipedia.org/wiki/The_Unreality_of_Time, (21 March 2007)

[9] *The Unreality of Time*, Wikipedia, The free Encyclopedia, Philosophical article, http://en.wikipedia.org/wiki/The_Unreality_of_Time, (21 March 2007)

C Series is the chronological order of events. Event that happened once in a specific moment carry the date of their real occurrence. They have a specific position in the time span and therefore Mc Taggart suggests that this order is not temporal. The time distance between the two world wars is defined and will never change. Nevertheless, as long as we focus on now, the distance between an event in the past and the present event is growing, because new ones are added. This observation is based on the tool of A Series, that Mc Taggart uses, that imports the relative movement of the now and therefore also the movement of every event in the time span. A past event flows in the distant past and a future event comes nearer to the now. Franck makes also this observation and therefore he introduces the second dimension τ, his tool in order to express the movement of the now.

The order of the individual time slices ∆t of Franck is based also in their relations of earlier and later, the B Series by Mc Taggart, Something is happened earlier or later than something else. The order of the events in the time line is unchangeable and the limits between them clear distinguishable. This kind of relation is the B Series by Mc Taggart. [16]

The order of individual time slices ∆ τ is also based in the relations of earlier and later, but in this case these interrelations are being on movement. They are unstable because they move in relation to the now that is self in movement.

It could be assumed that the dimension t is a combination of the B and C Series and the dimension τ is a combination of B and A Series. In both cases, time is approached as a phenomenon of higher level of complexity that demands more than one dimension in order to be described. Similar to complex shapes or systems like fractals, someone has to introduce new conceptual tools, like the fractal dimension, in order to respond to the demand of the mere parameters of the specific phenomenon

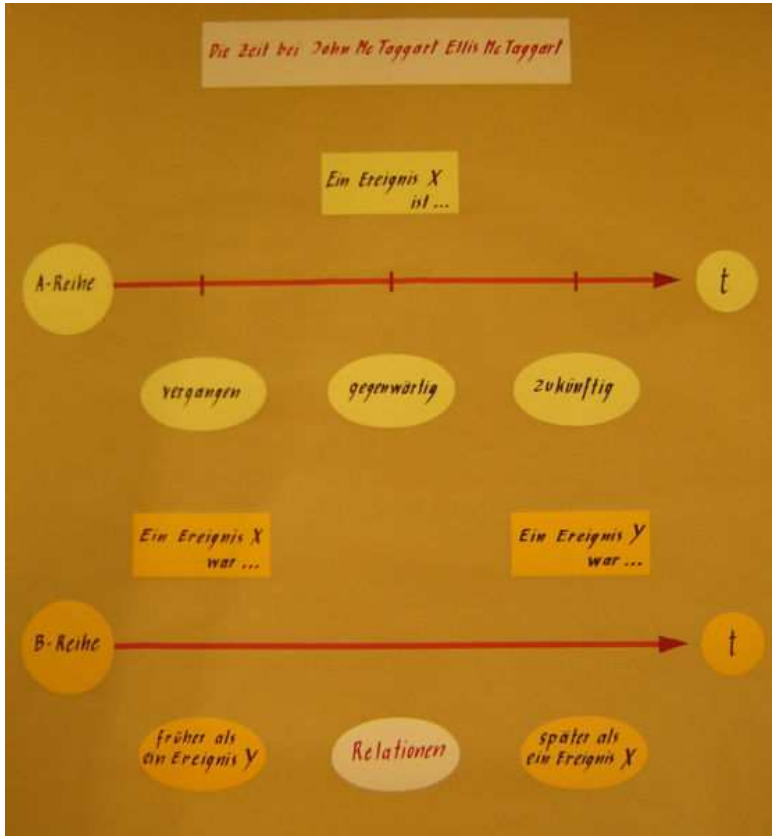


Figure 4, time series A and B by Mc Taggart, Source: en.wikibooks.org

By the A Series, the mutation from something that was one future is now present and belongs afterwards to the past is a temporal relation that is instable. The boundaries of the present are shifting all the time according to ones mental perception of future or past events. While time is running an event moves form the distanced future to the presence, getting closer and closer to the actual slice, until it becomes itself actual, and afterwards leaves its traces to the human memory. This kind of temporal mutation is described with the minimum quanta of chronon τ, the division of the axis of temporal change in $\Delta\tau$, time intervals that are related to the now. The cooperation of the two kind of time intervals in the orthogonal system, realize the essence of the flow of time and the continuous come and go of different events in time. (Figure 5)

The combination of the aforementioned time Series is necessary to describe the passage of time. Mc Taggart also points out that it is not enough to explain the change in time only with A Series. He comes to the point that if what change in time are the relations of past and future moments according to the present state, then one term of this relation is based in A Series and the other term in C Series, where the position of the event is stable. "The relations which form the A series then must be relations of events and moments to something not itself in the time-series."

Additionally, he mentions that if an event has been future is now present and will be past, there is a second A Series where this event is present in the future. An event being present in the future is an event that has not been yet realized. The second A Series aims at depicting exactly the possibility of future events. Until it becomes present an event can change or someone can choose between different possibilities. Belonging to future an event is nascent it emerges from present actions and decisions but remains still virtual, not real.

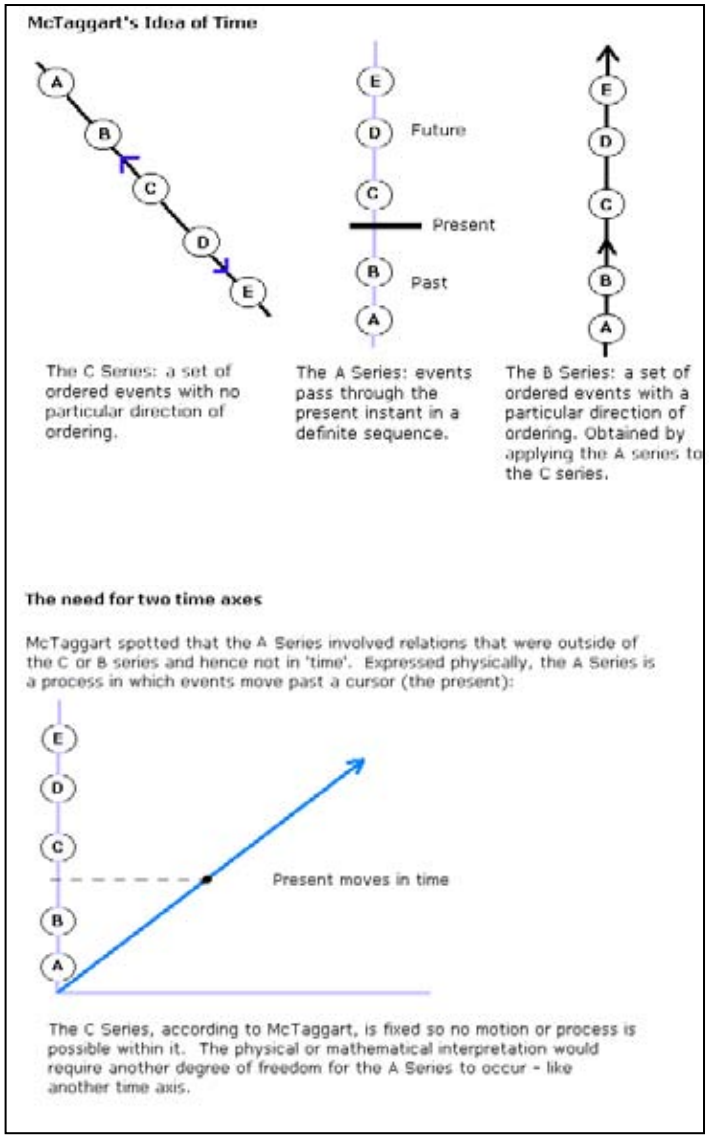


Figure 5, time series by Mc Taggart, Source: en.wikibooks.org

2.2.2 Cognitive map of temporal change

For Mc Taggart, the elements that change in time from one event to the other are qualities and temporal relations. Parallel to his suspicion that there should be two time series A which depict the possibility of future events he points out that also in the past there is a continuous mutation that distinguishes two kinds of past, distant and recent past. He writes "a past event changes only in one respect -- which every moment it is further from the present than it was before". A constant mutation of the past moment that fades out step by step as its distance from the present moment grows. Therefore, the two A Series are probably necessary not only to describe the idea of possibility and predictability in the future but also to distinguish the two kinds of past.

This statement declares that events and senses that belong to distant past are not as clear and intensive as the events that belong to recent future.

There is indeed a difference between distant past and recent past. Memories that belong to distant past are fade out as conscious experiences whereas memories that belong to recent past are more bound to the present awareness. Kari Jormakka writes in his book Flying Dutchmen [9] that for Bergson, all memories have the same kind of essence and duration is immediate: the past continues to exist in us. Kari Jormakka points out that the criticism of Bergson's contemporaries William James and Edmund Husserl on Bergson's thesis is that distant past can not be immediate in that degree that recent past is. Time distance defines two kinds of memory: immediate retention of the recent past and recollection of a more distant past. They suppose that time is not experienced as the succession of discrete moments, and the awareness of the present moment is connected with the immediate past through retention and with the distant past through recollection.

Despite the aforementioned criticism, this dualism of memory is also approached by Bergson [1]. He distinguishes two different states of our memory. Namely, the pure memory and the memory image. The first one is the weaker state of memory and the second one the powerful one. He addresses pure memory every information that is stored in our mind, regardless of the fact that this information is recollected by our mental present or is faded out and forgotten in the back of our mind. He names memory image exactly this information that we choose to recall and retrieve from the whole of our memories, because our present perception needs it.

Consequently, according to Bergson's thesis, there are also other factors that influence the hierarchy and order of our memory, not only its distance from the present moment. Our present perception may recollect easier an event that belongs to distant past than another one that belongs to recent past, because its context may be assigned more direct to the present experience. (Figure 6)

Furthermore, Bergson describes the act of recollection as an act "sui generis". He explains how human memory is connected to the present perception. Someone living in the present moment, detaches oneself from present state in order to attach oneself first in the past and secondly, in a specific region of the past. Until this point the recollection remains virtual because it's only a preparation of oneself to receive the final stored information. In order to do this, someone adopts the appropriate attitude.
For Bergson, virtual is not only the possibility of a future event to become real but also the possibility of adapting a memory into the present perception.

Following Bergson explains the procedure of a past event becoming actual in someone's present perception.
The memory someone wants to attract, comes into view among the fog and the cloud of stored memories, its outlines become more distinct, and its surface takes color it tends to imitate the present perception. This means that it tends to embody things we perceive in the present moment. Though the retrieved memory is detached from the whole group of pure memory it is not completely transformed to present perception. It remains memory by its deepest roots, and we perceive it as such. It embodies a part of pure memory that is now materialized and also coexists in our present perception. This is why Bergson names this memory image, nascent perception. (Figure 8,Figure 9)

In relation to our present priorities, views and perceptions the stored memories are ordered in hierarchical semantic structures in cognitive maps, according to their importance to the present experiences. They are strongly influenced by feelings, for example we remember events that are connected with positive experiences, or on the contrary situations that hurt us more strongly and clearly than others that did not erect our emotions. The order of those memories is based on subjective features.

Of that past, only that part that can collaborate in that action and make it useful becomes an image, namely the memory image. From the moment that it becomes an image, that part of our past leaves the state of pure memory and coincides with a certain part of our present. This is why memory image is memory actualized and materialized and differs form all the rest of memories. On the contrary, all the rest of our memory powerless as long as it remains without utility is pure from sensation and remains without attachment to the present.

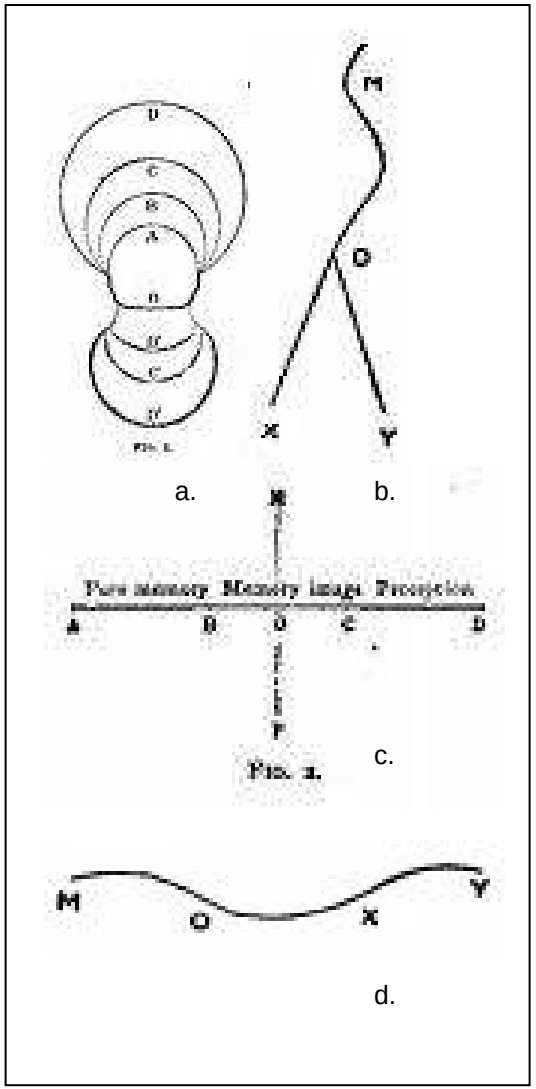


Figure 6 a. b. c. d, memory and present perception, Source: spartan.ac.brocku.ca

During every day's life actions and also during the building's process, we recall information, images or sensorial feelings from events that happened in the recent or later past. These documents are written in our memory according to the essential representation of them in our mental present. They are re-constructed in the present and exist only there. The memory image by Bergson describes exactly the reconstructed status of a memory by our present perception. (Figure 7)

In the case of the design and building process, the aforementioned act of memory recollection describes a recursive ongoing of moments forward and backward along a chronological time line axis in order to synthesize the information for the building object form in a precise moment.

Parallel to the mental construction of memory develops also the construction of future moments. We build our future events by making choices between several possibilities, anticipating, risking, planning, and dreaming about later in time, extending the limits of our present. The relation between the now with an event that happens after some time in the future, for example one day is different from the relation between the same now and an event in future that happens after one year. In the first case the now defines stronger the future, it effects its characteristics, in the second case there are more possibilities of change, more alternatives and the grad of unpredictability is higher. For Progigine[10] it is to plan the future is inefficient useless because the grade of uncertainty is high. He supports the opinion that in every technical or physical system with high complexity, -someone could argue that building is also a high complex system-there are factors that change its planned function and cause unpredictable behavior in time.

In any case though, every future event is in different scale influenced and constructed by the now. As a result, future exists only as a construction, anticipation, prediction in the now.

Figure 7, memory, Source: www.christianhubert.com

[10] Ilya Prigogine was a Belgian physicist and chemist who studied the notion of Uncertainty in Nature and Human Culture in relation to chaotic behaviour of systems. He is well known for his work *The End of Certainty* and also *Order out of Chaos : Man's new dialogue with nature*

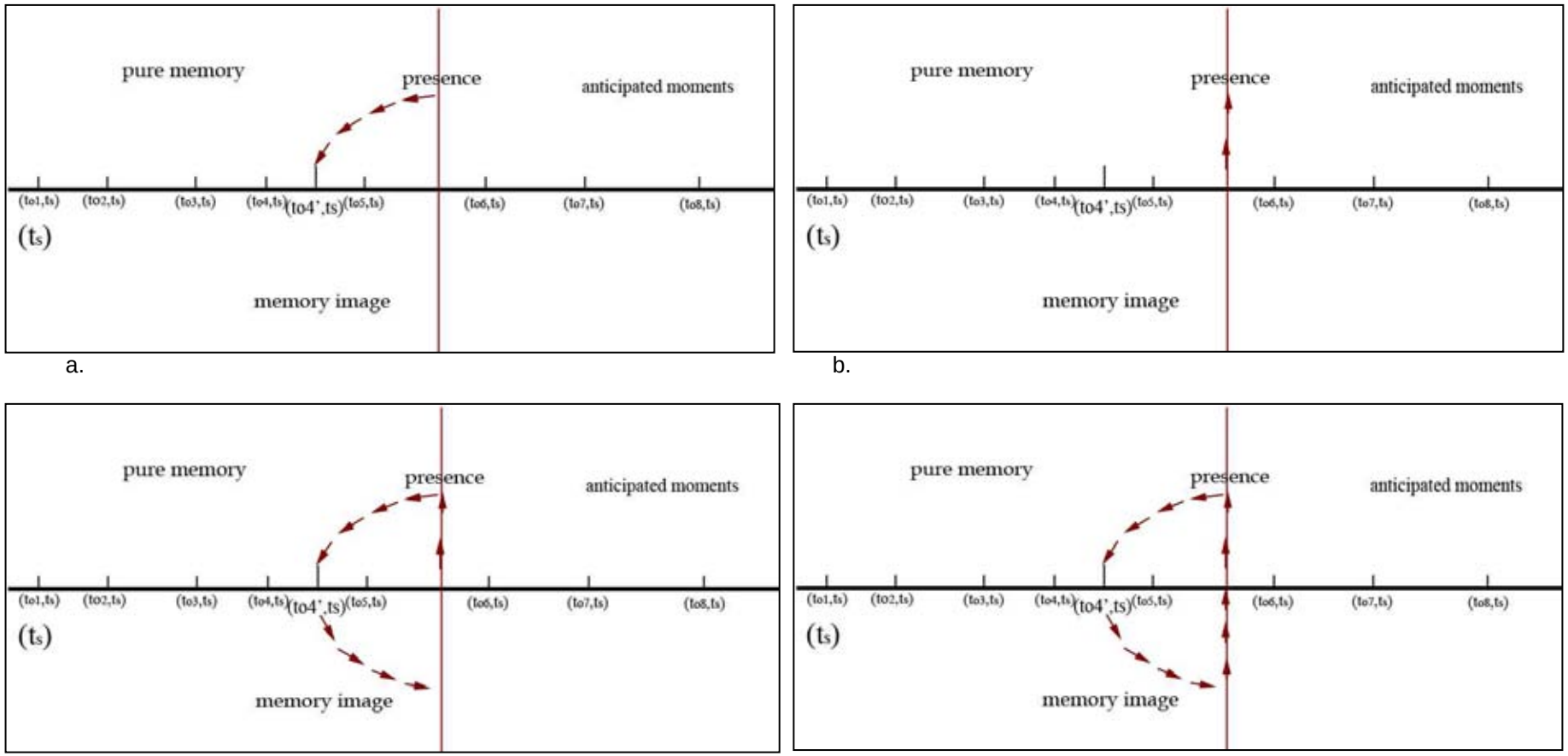


Figure 8 a. b. c. d, memory image / pure memory by Bergson

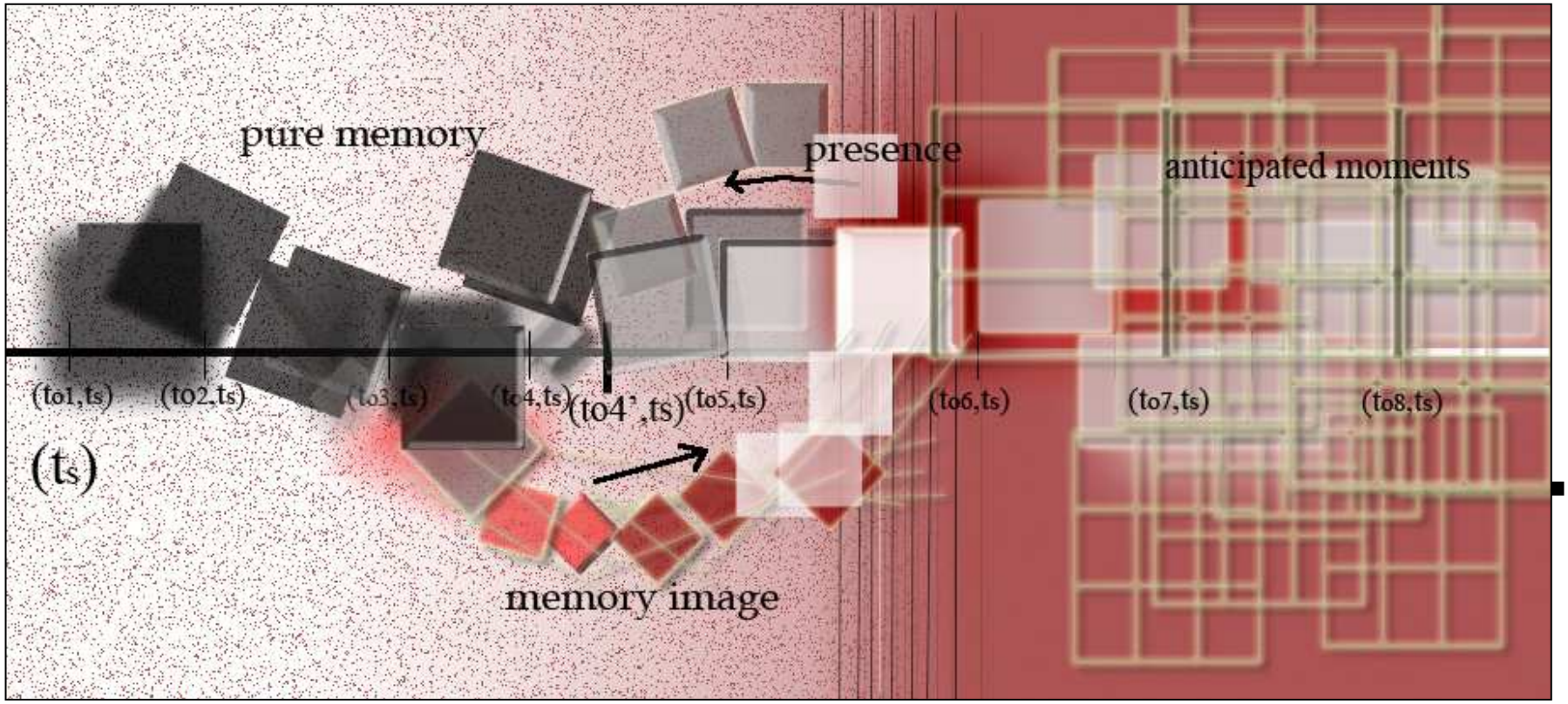


Figure 9, memory image / pure memory by Bergson

2.2.3 Recollection of memories, anticipation of future actions

Similar to the approach of Bergson on the essence of memory image as the reconstruction of the past by the present perception, G.Franck points out that we have no immediate access to whatever kind of reality of world states that have passed or are yet to come. All we know, or think to know about things happened in the past or assume to happen in the future is constructed from information available in the present.
This is why events that are past or future carry two dates: the date of their supposedly real occurrence and the date of their actual imagination.

In relation to the orthogonal system t, τ the hyper membrane[11] (3D + Δt) of the now is the time slice when t i = τ j traveling through the world states. (Figure 10) Considering that the axis τ describes temporal relation of the now to future and past, the moments for which it is t i < τ j belong to the past whereas t i >τ j belong to the future.
Along this traveling, the present hyper membrane leaves behind the traces of the past which are more intensive near to the membrane and become more invisible as long as their distance from now grows. These traces are the memory of the system, and their representation as data entities constitutes a cognitive map of the past. Additionally, the mutation to the future consists from possible paths that, similar to the traces of the past, they are more intensive near to the membrane and more loose and blur as their distance is longer until they reach the now.
The limits between these temporal conditions are unstable and loose, while they keep constantly changing. (A Series). [16].

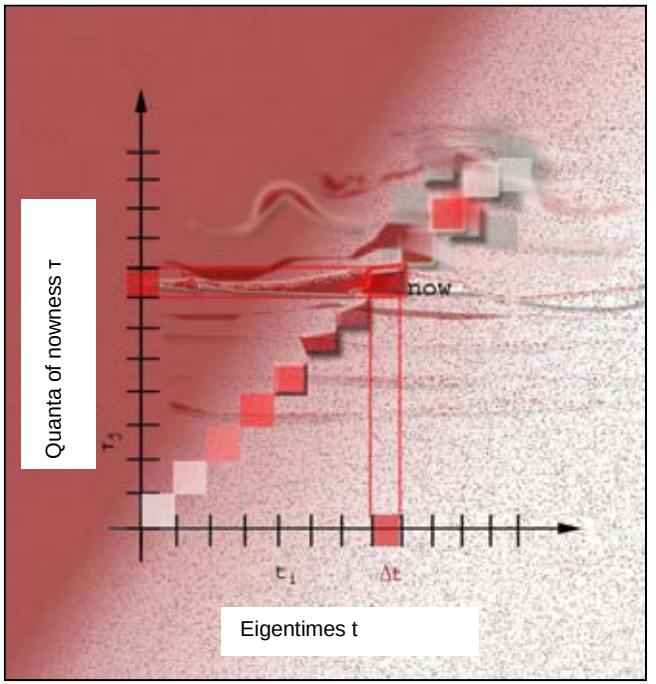


Figure 10, the traveling of the now

The chronological order of memories provides a structure of ordering information. In this case, events are recorded in the cognitive map of memory in relation to two kinds of dates. The date of their real occupancy, when they really happened in time, and the date of their entering in the cognitive map, when they are recorded.(C Series) [16].
The events that are reported on the time line have two dates. The date of their real occurrence and the date of their report in the schedule time line. (t o object,t s system) .
This dimensionality as valid time and transaction time [22] consists of these two dimensions that are not homogenous; they are orthogonal and have different semantics. The position of the events in the time line is fix and unchangeable. Alone this order gives no direction either to the past or to the future. It is the kind of C Series by Mc Taggart.

In addition to those dates, every time that information is retrieved from the cognitive map of building memory a date is added, when this information has been reused in someway.

The current research thesis explores the concept of a model that could operate as the building memory[12]and also report its behavior during its life time. It presents events that are reported in a chronological sequence (C Series) during the life building process and visualizes parallel temporal changes between earlier and later stages of building statuses (B Series)

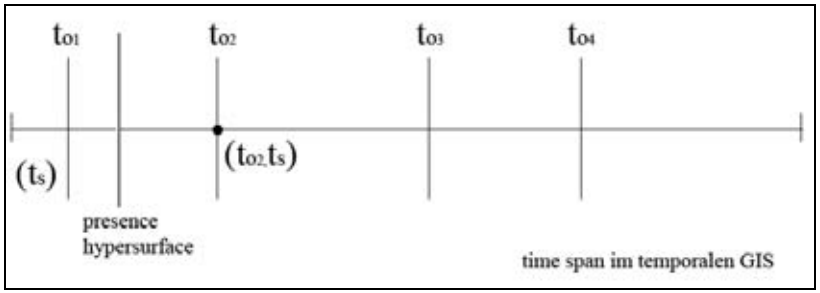


Figure 11, object time/system time

This model would help the architect or design participant to follow the architectural project along its development in the passage of time, through the several phases of its life, reporting the decision and inputs that influence its performance.

[12] The term building memory is used as the name of the software developed by Papalexopoulos and Kalafati [19]. The software is a multimedia building construction system of several databases that provide information about the history of each building, its construction techniques, and its material and visualize the construction process. http://www.ntua.gr/archtech/buildmem/

3 BACKGROUND: Review of 4d technology

An important research progress is done in the field of 4D CAD, in order to incorporate time in the architectural visualization and the design procedure. The subject of time and time flow was always a topic of a grate interest for the architects mind. There are several approaches in research regarding the dimension of time. Each of them incorporates time in different part of the design and building procedure. Time is related in each case with the notions of change, motion, transformation, complexity, life expectancy and scheduling data.

3.1 The dimension of time in architectural design

In the design, time is incorporated either as a metaphorical concept, or sometimes literally, when several parts of the building, or the whole building moves. The technological development in the field of architectural design and building science brought the computer in the first place of use among the design tools. Design and representation of the architectural object are the result of mostly computer work. After the capture of the first idea, on paper or in the computer, the design is realized with 2D and 3D cad applications. The 4th dimension of time is sometimes incorporated in the design procedure, like the dynamical forms that Greg Lynn creates in computer. The architectural object takes several transformations until its final crystallization. (Figure 13,Figure 12)

The final form then incorporates as traces, all the movements and changes happened during the passage of time. In other cases, the dimension of time is approached with several applications for 3D visualization, that support a VRML-virtual reality modeling language- environment, where the architectural object can be observed from several views through the movement of the user around the object or in the inner space, walking through it.

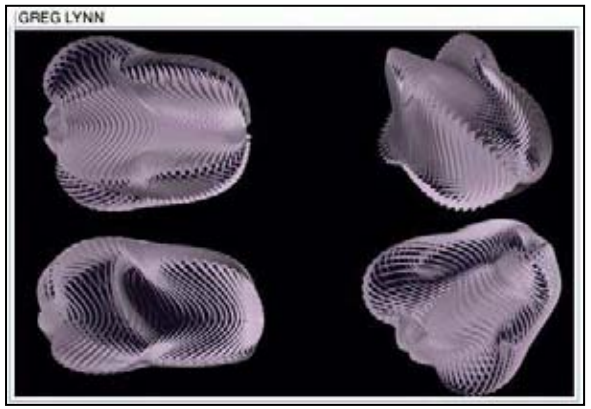


Figure 12, Embryological House, Source: Lynn, [14].

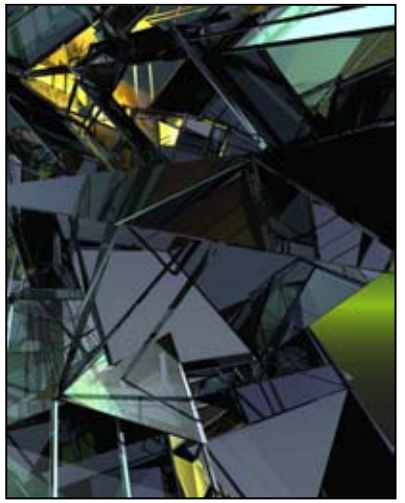


Figure 13, 4DparisN, Source: Novak, [17].

3.2 The dimension of time in building science

In field of Building Science, there is a research going on in the subject of virtual building life-cycle. The aim of this research approach is to give access to the architects to the future of buildings, by visualizing life-cycle data. So, the architect can have an idea for the life performance of the building before it is actually build. The project “Virtual Building Life Cycle” (VBLC), by Dipl.-Ing. Christoph Linnert, Dr.L.Miguel Encarnacao, Dipl. –Inform. Andre Stork from the Frauenhofer Center for Research in Computer Graphics, and Dipl.-Ing. Volker Koch from University of Karlsruhe. [12].

It connects 3D geometrical information to research data such as life expectancy, emissions and to standard database information like prices, in order to visualize the future life of the construction, through the behavior of the materials and building parts. The prototype implementation of the VBLC is an extension to the 3D Modeling System ARCADE. The plugin VBLC supports interaction, visualization and navigation techniques. The program provides rapid access to numerical and graphical information from a database. The user can choose among several visualization modes and it is possible for someone for instance to walk though the building while it ages. (;Figure 15)

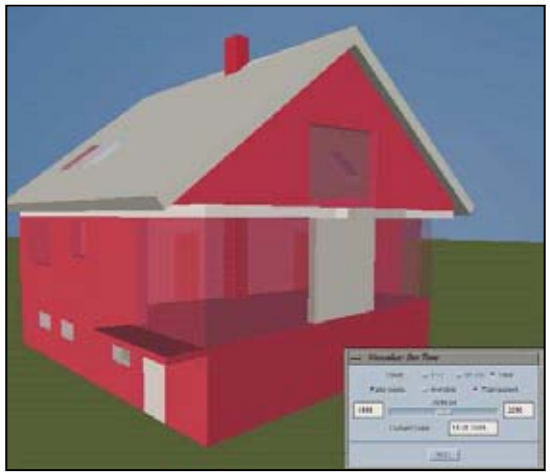


Figure 14, visualization of the behaviour of materials after the passage of time, Source: [12]

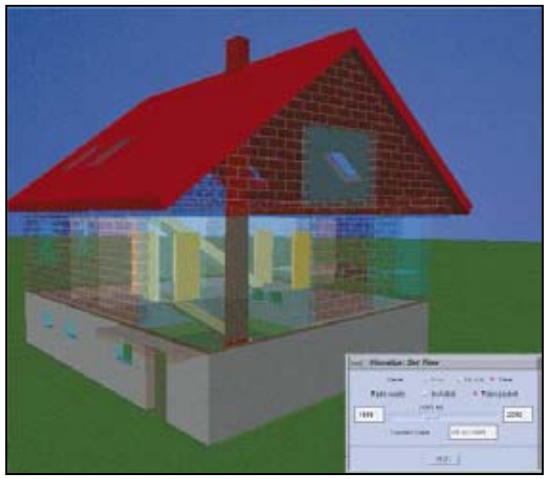


Figure 15, visualization of younger and older materials, Source: [12]

3.3 4D CAD in construction management

Another approach of the 4D modeling, the 4th dimension of time, is the research subject of the Civil Engineering Department in the University of Beijing and Hong Kong, in China, focusing in the automation in construction [25].. The 4D Site Management Model links scheduling data to a 3D computer graphics building model. 4D CAD tools aim is to show potential conflicts in the construction site, to practice what-if analysis so they can access and compare several planning options to select a better strategy. Recently. 4D concept has been also extended to incorporate also other fields of the building construction process like resource management and cost analysis.

The term 4D CAD is a concept that was first used in the Stanford University. By M.Fischer and his research team [4] Time is in this case used in the simulation of the construction process. Every step is linked with scheduling data and associative information. There is a time based module that attempt to integrate design and construction decisions and activities. New research topics on this field focus on interactive 4D models, where the user manipulate the 4D content in order to improve the use of these tools in the construction planning. (Figure 16,Figure 17)

Figure 16, 4D Cad, Source: [25]..

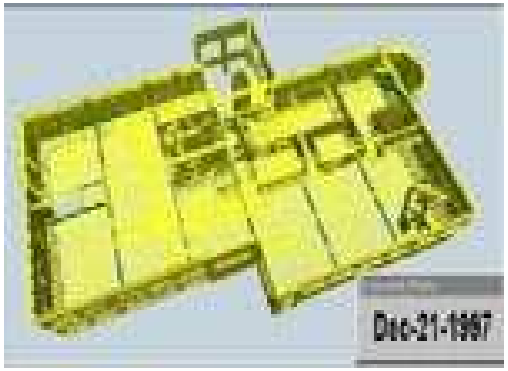
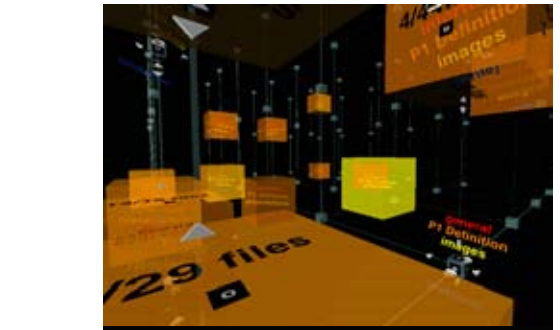


Figure 17, 4D Cad, Source: [4]..

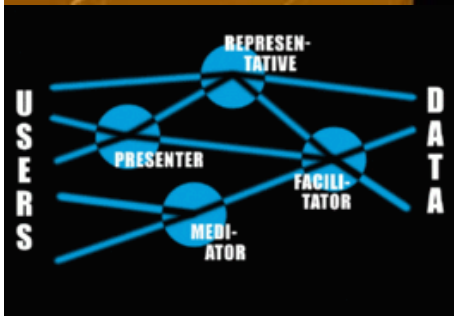
3.4 Dynamic Information Structures

Time is not only used in dynamic building models but also in dynamic information structures and databases. The project A Virtual Tool for the AEC Company [13]. is a research project developed by the Federal Institute of Technology ETH Zurich explores innovative and dynamic ways of representing data concerning the building industry in a user friendly environment. Organization, storing and retrieving of information packages are focal points that are developed by autonomous dynamic mechanisms, where in many cases the visualization of the data source changes in time in order to provide a better understanding by the user.

Additionally, the interesting part of this project is that the information environment is a common technical platform for information, communication, and collaboration between several components in the building industry fields such as in building planning, design, construction, and management processes. It is therefore a multilevel information structure that runs in parallel times, linking the work processes of different participants. A variety of tools and media manage parallel and collaborative actions. The software Sculptor applies collaborative modeling, a web-based interface links to information database about cost analysis of the project, the delegates isolate a specific function of the system and mediate between the database and the user, for example they support contact (messages or mails), decision making (time schedules, meeting information calendar) and the overview of the project (cube delegates)(Figure 18)



a.



b.

c.

d.

Figure 18 a .b .c .d, a Virtual Tool for the AEC Swiss Company,

Source: [13].

4 CONCEPTUAL TOOLS

The model introduces the idea of the structure of an information environment based on the dimension of TIME in the life of a building object, from its design and during its life to its collapse.

4.1 General frame

As analyzed in the theoretical part of the research project there are going to be used the following conceptual and structure tools:

- A cognitive map of actions and decisions happened in the past and others that are anticipated in the future.
  The model will describe the building's memory and also its anticipated projection in the future. The information environment consists of the virtual library[13] interface, and the visualizations interface.
- The A,B and C Time Series are the spinal column of the information environment. Each of them separately supports the information structure ordering the data in successive points in time.
  A, Series
  A dynamic movement of the present moment from the past to the future and a second
  C ,B Series
  The chronological sequence of actions is indicated in -the time line schedule

- The present state is the core of the concept, presented and visualised as a dynamic state that impregnates traces of the past and moves to a nascent future development. Its boundaries between past and future are shifting constantly through the passage of time.

Temporal changes of the present state are reported according to three focal categories:

- Geometry of the building
- Economical assessment
- Administrative information

[13] the term library is used as the functional description of a conceptual space, a synonym for bibliotheca. It is not used according to the software language as the collection of objects or attributes of the same or different categories.

4.2 Analysis of the conceptual tools

4.2.1 Cognitive map of building memory and future planning

The cognitive map has the form of a virtual library, a bibliotheca of all information concerns the design and building process. The information stored in this library draws the history of the building but also its future steps planned through the design or construction procedure.

Virtual library interface
The unit that bears every kind of information is
-the cube[14](Figure 19)

The spatial relations of the cubical structure are defined in an orthogonal coordinate system where the

The x-axis is the time line schedule
The y-axis depicts the project tasks
The z-axis depicts the design information outputs and the monitoring information output from the realized object-

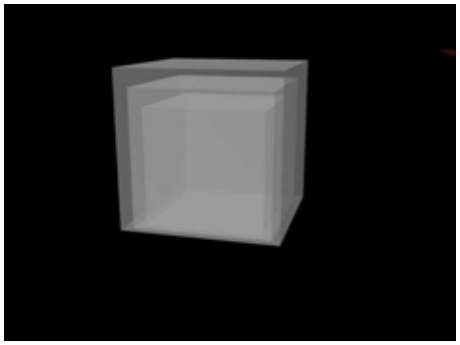


Figure 19, information cell

In every step, the present moment can be indicated by a red vertical line, the time slice. The time slice (hyper surface) of the present state is indicated by the red color.

The cube with the present, actual information is indicated by the white color

B Series
The relations of earlier and later relations are indicated by the transparency scale. After indicating the present state of work during the project, every information cell –cube- transforms according to a transparency scale. The cells that are placed in distance from the present moment are transparent, their essence is weak. On the other hand, the ones that are close to *now,* are less transparent, because they influence strongly the present state and additionally they are directly controllable.

[14] The idea of the cube as an information cell is common. In the project *A Tool Set for the Virtual AEC Company*, a web-based information platform for the Swiss building industry, developed by the department of architecture in the University of ETH in Zurich [13] , there are cubical *delegates* that structure an information environment that mediates between the user and the data. The size and the color of the cube reflect the number of documents they contain. The user can have an overview of the whole project by observing which cubes have been changed recently and driven through the cube to the main interface.
In the ACADIA international design competition in 1998 (http://www.acadia.org/competition-98/winners.html) entitled *Library for the Information Age* [26], the student team of the National Technical University of Athens of Greece that won the third price proposed a structure from cubical cells that would store every possible information.

The symbol of the cube is chosen to represent the information cell, the information unit in the virtual library. In the horizontal "shelves" of the library, along the y-axis, the information cells are arranged along a time line that indicates the most important schedule arrangements, which influence the several steps in the buildings life. Along the x-axis, the information cells are arranged according to the different kind of design tasks who cooperate in the project under the work of different components such as engineer consultants, construction firms, contractors, project owners and project managers. (Figure 21, Figure 22) Finally, in the vertical "shelves", along the z-axis, the information cells are arranged according to different kind of information outputs, such as different file plan formats, 3d model design, images, presentations, sketches and notices. (Figure 23) According to this structure, a cube-cell may store for example information about the building permission design status, after a meeting between the architects and the civil engineer consultant, in an outfit of several sketches. The user can navigate to the content of more than one cells parallel, in order to combine information for example between two important dates, extracting plans, sketches and images.

The aim of the library model is not to represent the design information directly, but to represent the links to the information. This is the reason why it is chosen the cube-cell library model as an abstract way of visualization of stored information. The library model does not visualize the context of the design information itself. It visualizes temporal relations, like time actuality and duration, density and repetition of information.

Along the three orthogonal axes there are labels that indicate the kind of information at a specific point in time. (Figure 20)

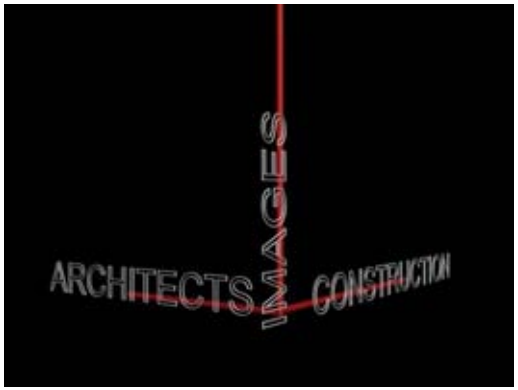


Figure 20, the three orthogonal axes

Browsing the data cells, information concerning the process of the building object appears in the visualization interface.

4.2.2 The interaction window

The window is the portal to the virtual environment of the library and the design object. The 3D space is interactive, the user can move and orient in real time inside the 3D modeling space by moving and dragging the cursor. The 3D interactive modeling space can be supported by applications such as 3D Acrobat Reader , or BS Contact VRML / X3D, which allow the user to move the design object from different views, or to position the observer eye in different positions to better understand the space.

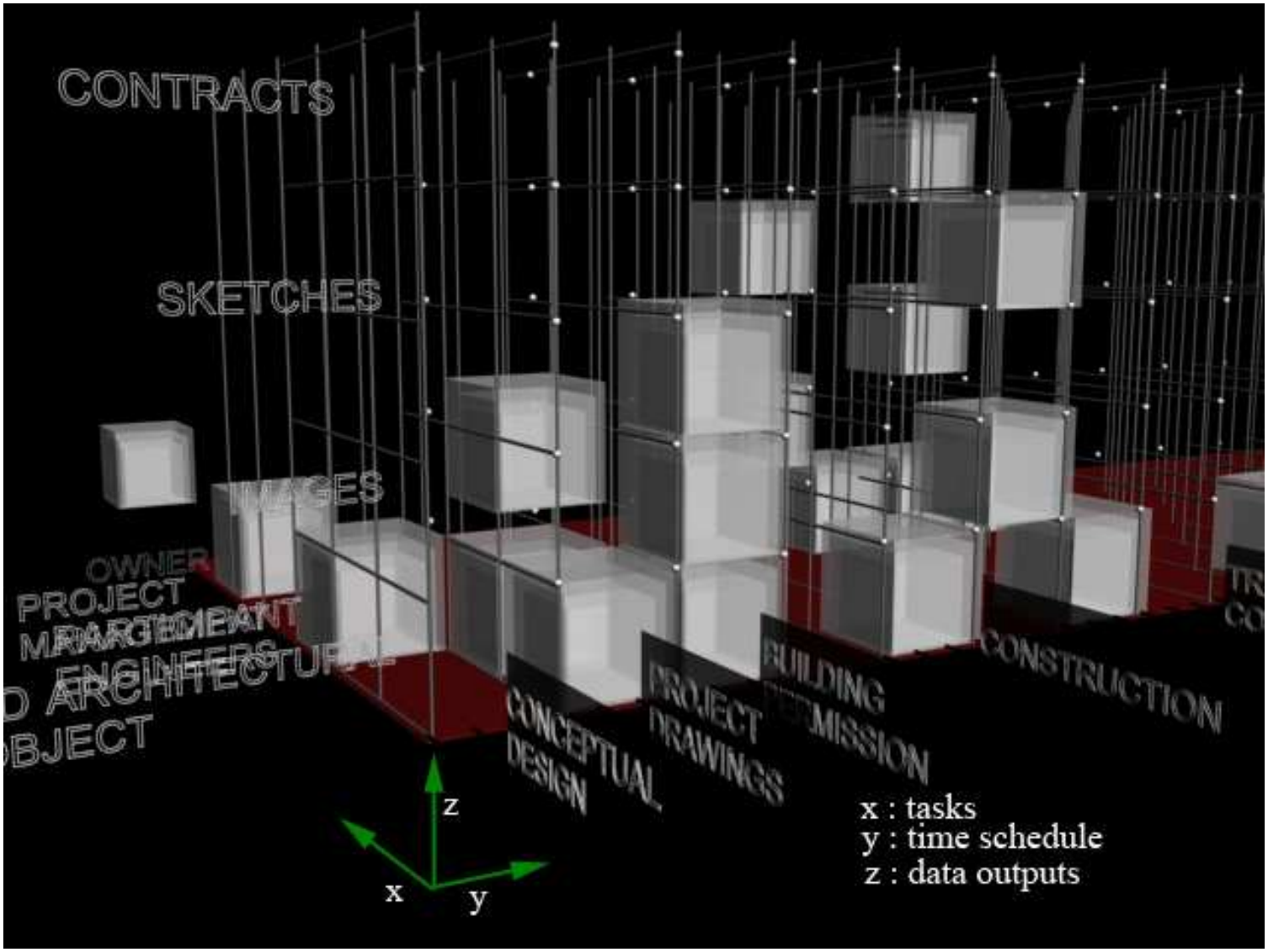


Figure 21, virtual library / x, y, z axes

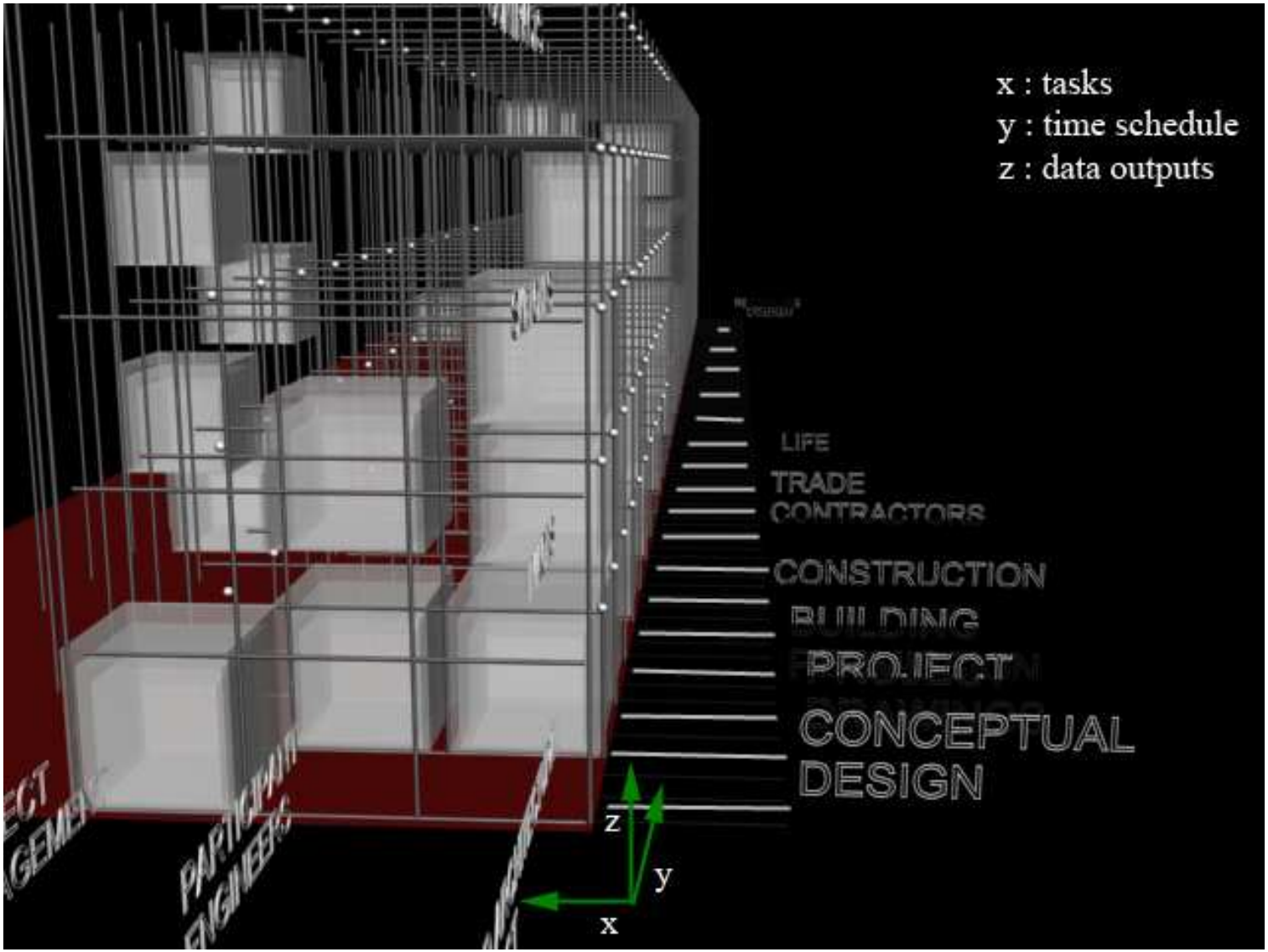


Figure 22, virtual library/ y axis

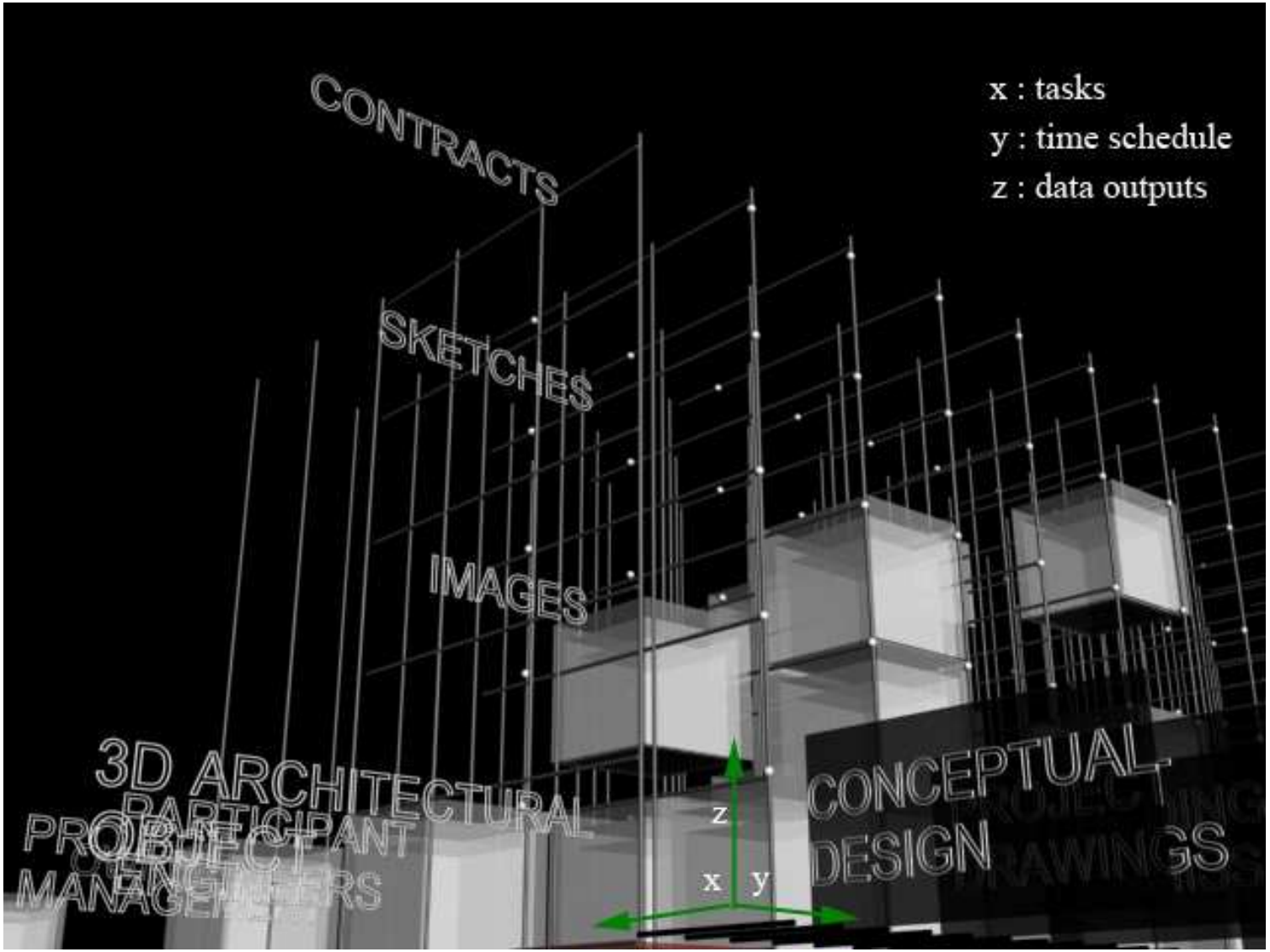


Figure 23, virtual library / z axis

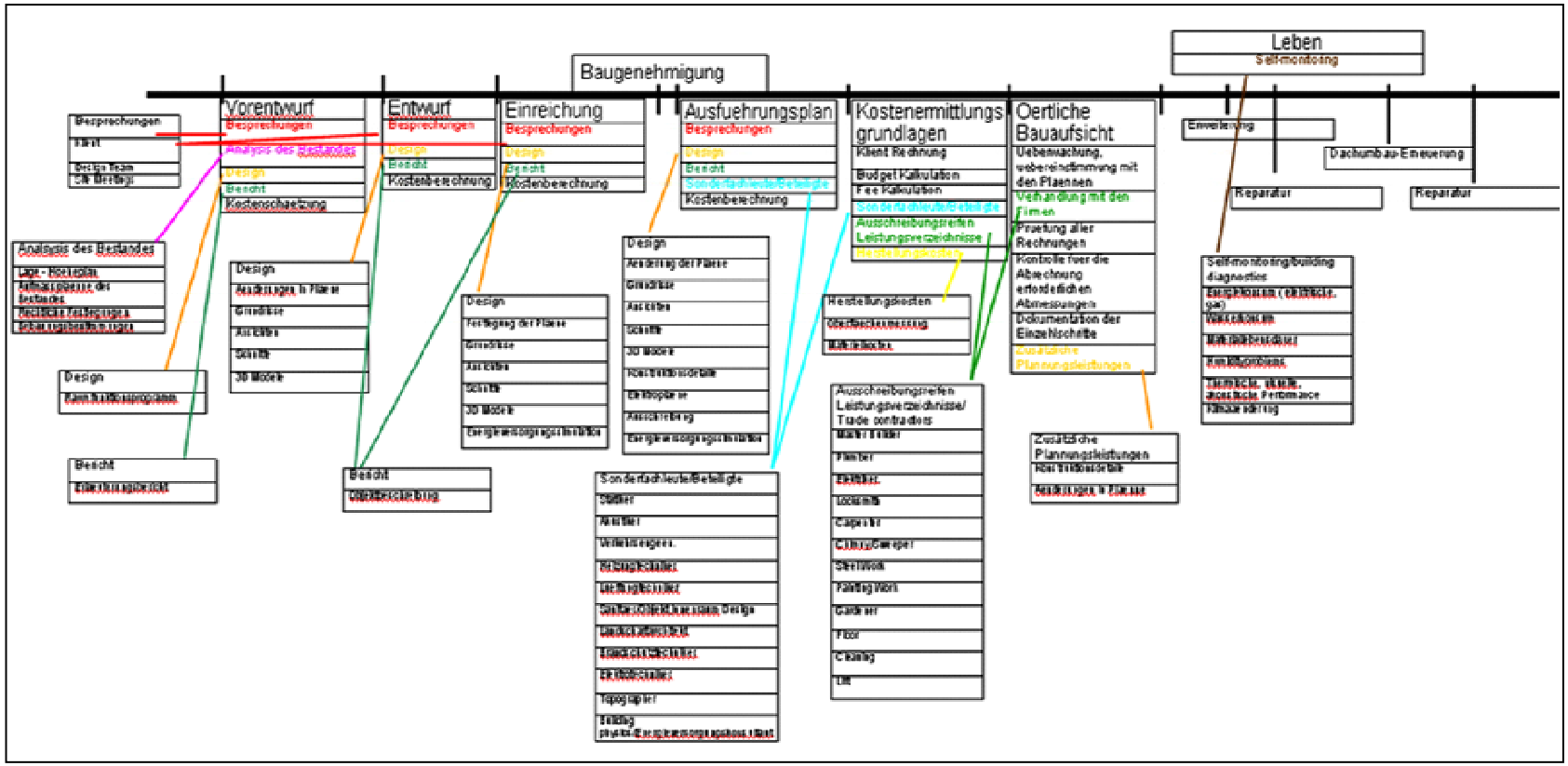


Figure 24, draft for a time schedule

4.2.3 Time series (A, B, C Series by Mc Taggart)

The time line schedule is the spinal column of the information structure. It is a diagrammatic schedule where all the important facts for the life of the building are denoted with their exact date, following a chronological sequence. (Figure 25)

Every separate step has its one characteristic that defines its ontology. (Figure 24)

The time line denotes specific points in time, for example (25 September 2005, Construction), or a time span between two dates.

In case that the information is not reported in the time line schedule the date when it happened it carries also the second date, namely the one that it is reported in the data base.

On the time line there are four discrete phases in the life span of the building indicated:

Design phase
Construction phase
Life time
Recycling

Nevertheless, the design phase is continuing also after the realization of the project.

The four discrete phases are divided further according to the needs of every project

In the Designs phase there is the step of
The conceptual design
The project drawings
The building permission drawings
The building permission

In the Constructions phase there are also several progression steps.

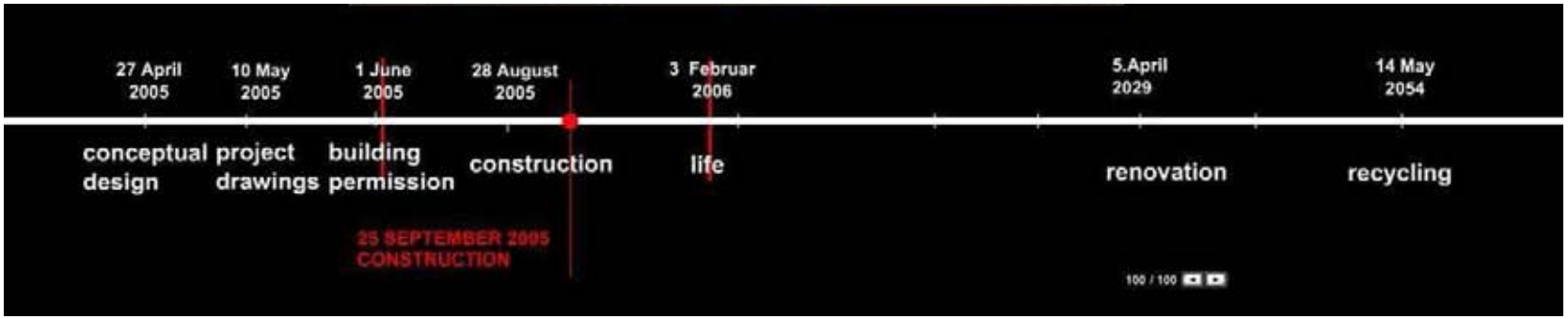


Figure 25, time line schedule

In the Life's phase there are stages of:

Reparation
Renovation
Extension

In the time schedule every action during the aforementioned phases is store as an event with specific date and additional administrative descriptions like the meeting reports that specified the end of a process and the beginning of another, the geometrical object that is stored at this point in time and the cost assessment of this stage. These events are imported as non changeable facts. Their position in the timeline is always the same. Before some latest facts and after some others according to the chronological sequence of time process.(C Series) [16]

Observing time process not as a linear alignment of events that happened in the Past, Present or Future but as an interrelation of Earlier and Later (B Series) the model applies the visualization of a time span in the building process, between two events that happened in different dates. There is an actual stage of progression that indicates the present and other stages that happen earlier or later than the present one. In this case, the model focuses and maps the temporal relations between the different stages and the changes that happen during this period of time. It creates a mental map which stores the past experience of the previous steps and indicates possibilities for the future steps according to someone' insights, free will and responsibility in making choices. A series of geometrical objects are visualized where the transparency scale describes the temporal relations of earlier and later and the use of colors indicate the parts that have been modified.

4.2.4 Ordering along the timeline

The design of a building is the result of a complex and multilevel process. To build up the concept of the architectural object, the architect in cooperation with several project participants has to consider and combine the parameter of form and function, the socio-historical frame, the techno- ecological parameter and the ergo-economical needs of construction facilities. The ongoing merge and polemic of the aforementioned parameters build a mutative plateau that can develop through the creative thinking of the architect in an innovative idée realized in the design object.
The realization phase, the building permission and the construction phase, undergo also such a level of complexity.

The life span of the building process develops from the design phase to the construction, then the operational time and in the end the recycling. The design phase consists from the part when the main concept is worked, then comes the drawing procedure, the building permission plans and finally the building permission and the trade contractors.

4.2.4.1 Designs phase

The discrete design phases develop non-linear. There are a lot of "going back", repetitions and overlaps of actions and decisions in the design procedure. The architectural object is the result of the interaction of several parameters. Functionality, form, ecological performance, integration to the natural, urban or sometimes historical environment, innovation, originality, costs. In order to make decisions and to focus in crucial for the project parameters, a lot of participants take part in the design procedure. The architects, specialized designers, engineers, the owner, the authorities. The design is influenced by every participant and the meetings between them denote mostly the end of a work

phase and the beginning of the next, under the spectrum of new information and inputs. Sometimes that means that the architect should do steps backward in order to recall some older version of the design. The current model aims at recording every step of the design procedure, storing the important information the plans, documents, pictures, notices and the older versions of the architectural object in order to help the designer have an overview of the development of his work, the inputs and information that lead to changes and the different versions.

4.2.4.2 Constructions phase

The next phase is the construction procedure. The design is continuing with changes that should be made and further details for specific parts of the building and technical function of materials. In several cases, the building construction is monitoring with cameras and multimedia tools. The current model incorporates the monitoring shots and aims at comparing the real constructed result with the design model. The comparison will indicate the parts that have been changed during construction and the reasons that caused the changes. In the construction field the 4D building model links construction activities with scheduling data and administrative information. It supports the overall control of the construction utilization and management and aims at improving construction planning decisions by presenting the behavior of the building structure before it is build.

4.2.4.3 Operational phase

The building begins its *life*. Human behavior interacts with its build surrounding and they construct patterns of environmental relationships. Human change it's surrounding according to own interest in order to create a safe environment significant for its physical and psychological needs. (Ecological valency) [15] Additionally, also human nature transforms in order to adapt these specific attitude to integrate successfully into the nature and constructed surroundings. (Ecological potency) During the lifetime of the building and its interaction with living and non living components, data concerning the temperature, its needs for lighting, for thermal and cooling energy consumption could be automatically traced and reported in a data base. This data base could function afterwards, as an informational background to optimally maintain and control the building. [12]

4.2.4.4 Recycling

Buildings have a life cycle which is materially and temporally defined. It is interesting to think hoe they could be transformed into new patterns of life, which will undergo continual functional transformations, like the landscape. The different material parts of the building would be apart, with new values added, new life cycles and new interactions with other living systems. They could be transformed into new building structures, or into new material combinations through the appropriate technical procedure.

4.2.5 The actual state: Interrelation with previous and future steps.

The aim of the 4D virtual library model is to provide an interface where the user can easily navigate through the stored information of the building and follow its development along the passage of time. (Figure 27, Figure 28)

In order to depict the temporal relations of past, present, and future, the model adapts the ordering concept of contiguity and rotation.

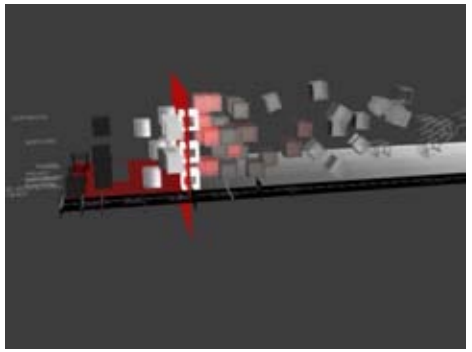
4.2.5.1 Library model interface: Ordering and Interaction

The red slice of the present state attracts the surrounding cells into a short distance from the time slice. The past events that belong to the recent past and the immediate future steps that follow the present state interact with each other, because not only the spatial but also the temporal distance form each other is very short.

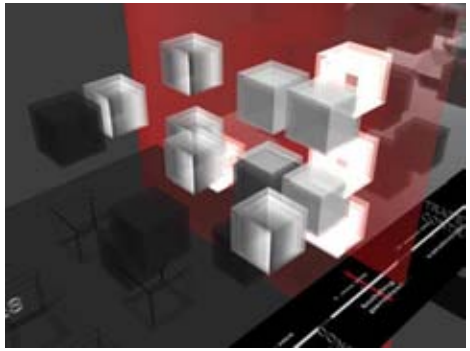
The cells that belong to distant past are loosing their lightness, their essence and step by step they become transparent and fade away.

The cells that belong to distant future are similar blur and unstable, therefore they are depicted as rotated and moving cubes. The ability to predict and plan the distanced future is difficult sometimes non reliable. (Figure 26, Figure 29)

a.



b.



c.

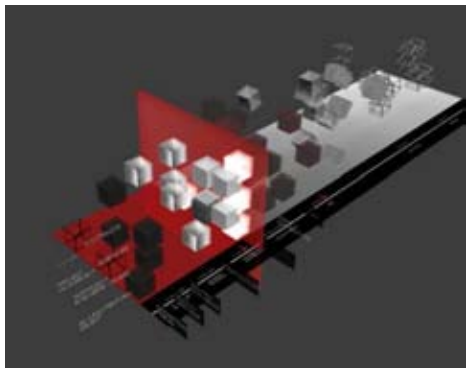


Figure 26 a. b. c., the actual state of present moment

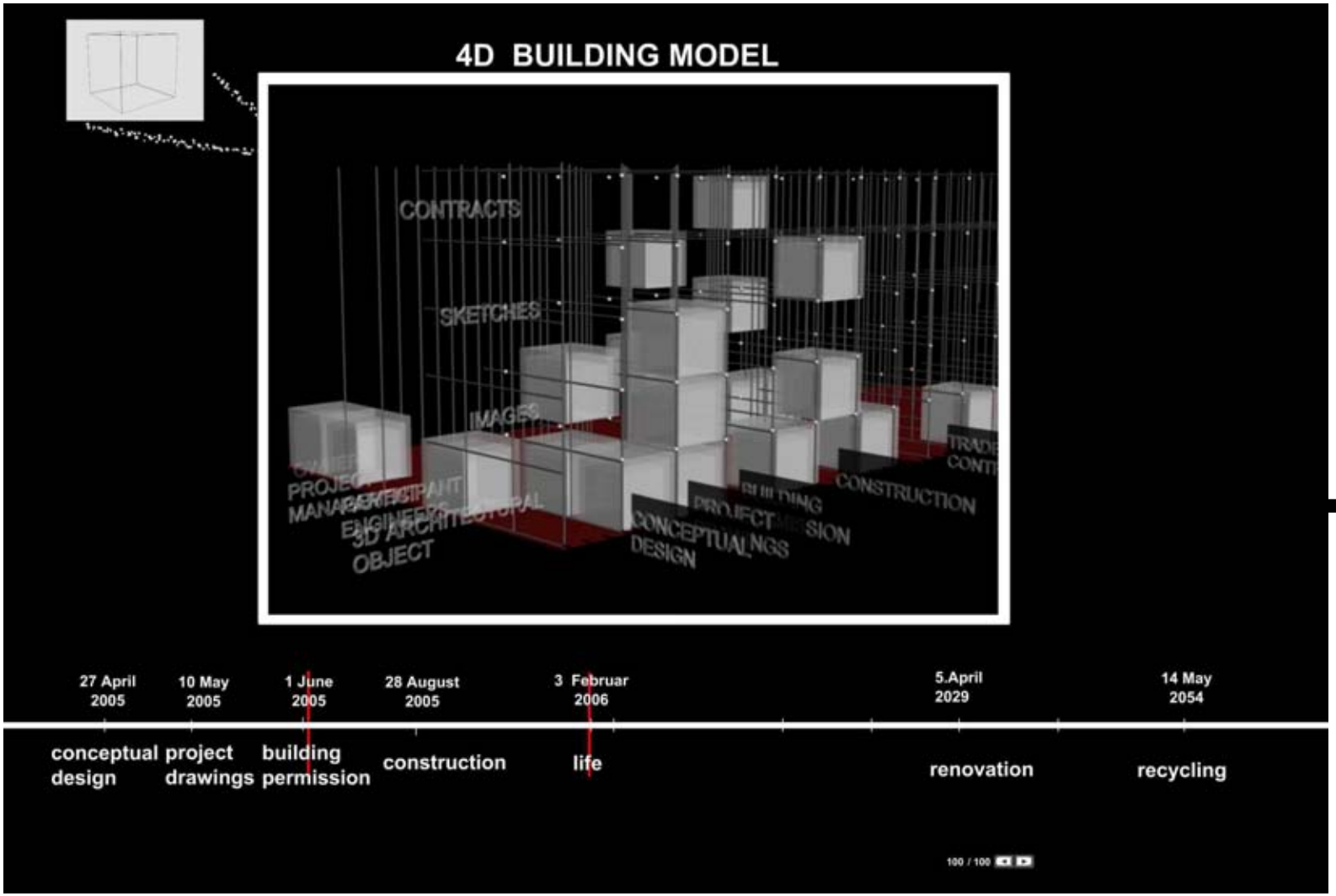


Figure 27, virtual library and time line

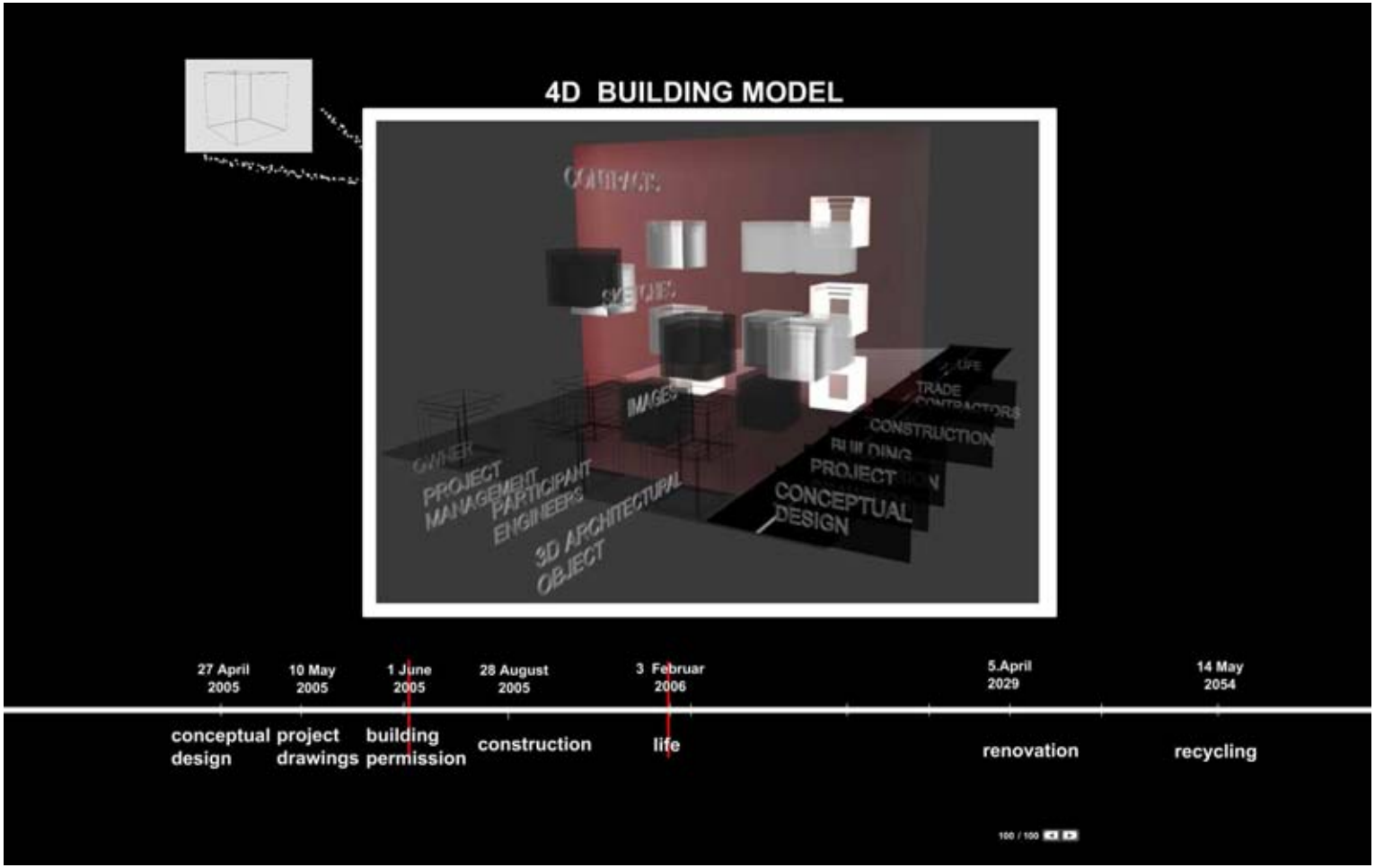
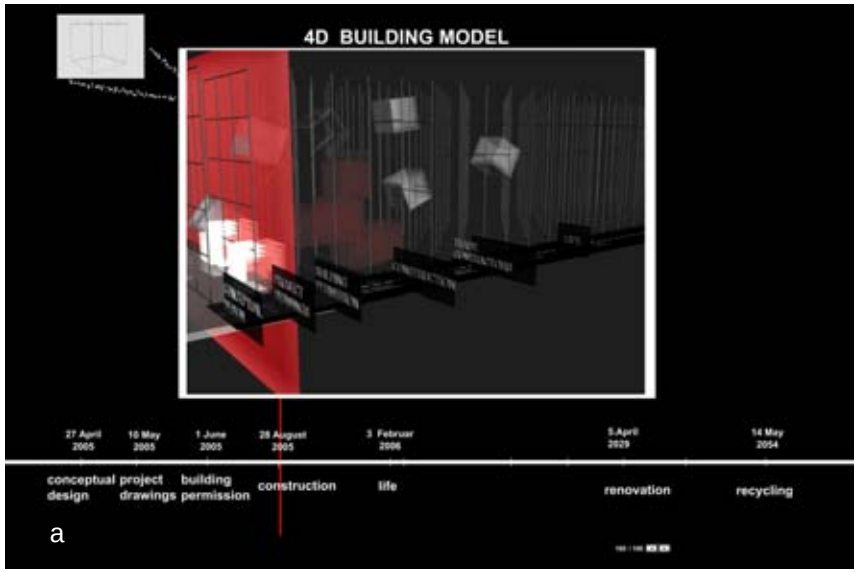
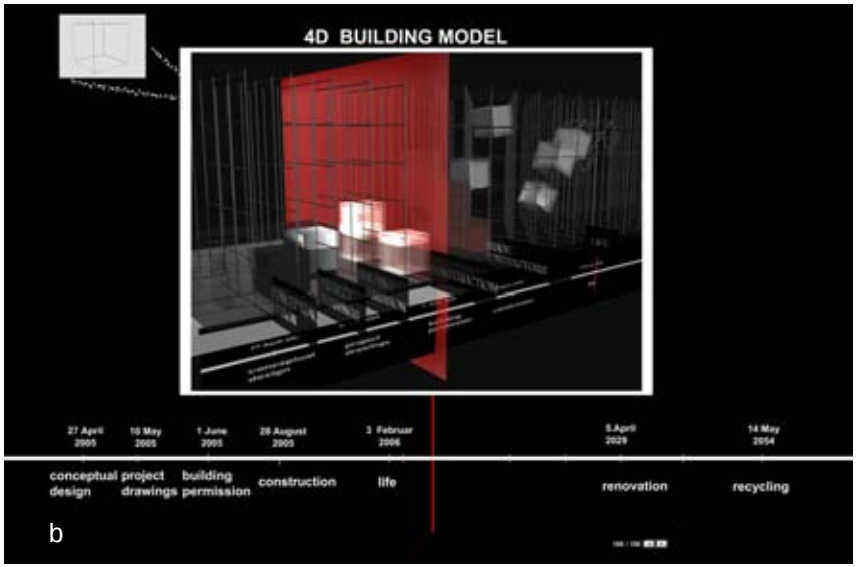


Figure 28, virtual library





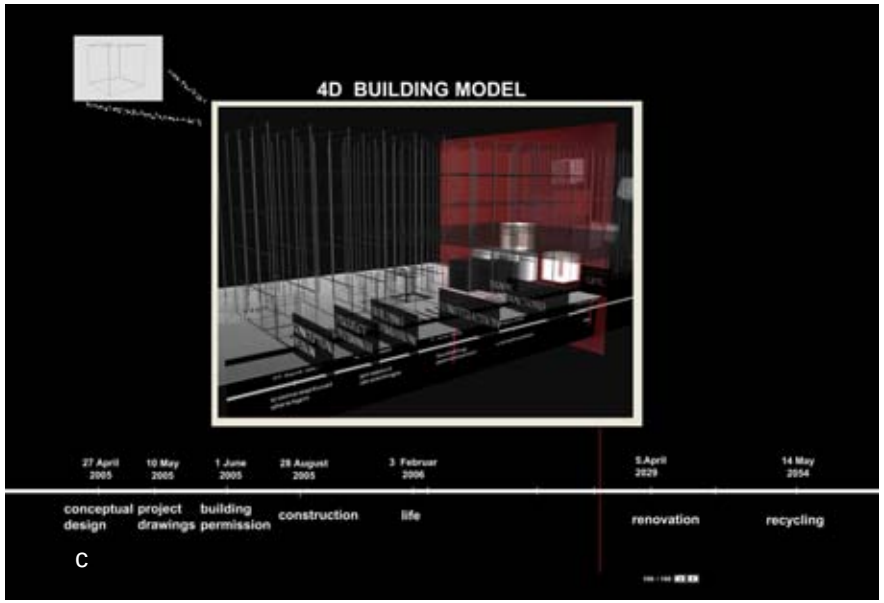
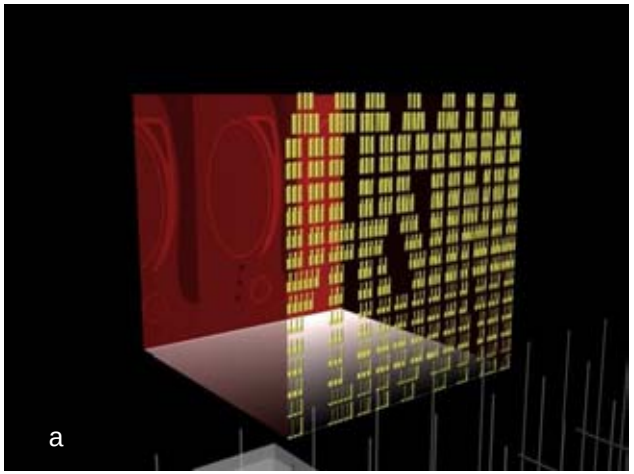


Figure 29, a. b. c, the actual state moving along the time line axis



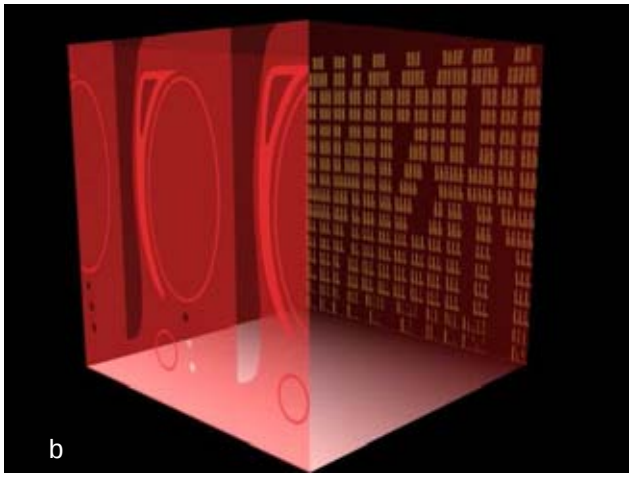


Figure 31 a. b. different faces for the three kinds of data

4.2.5.2 Versioning of design objects

Every cube stores in it three kind of data. Geometrical data, cost analysis and estimation data and administrative data. The three data types are not clearly separate. They often overlap and influence each other or define each others way of developing. (Figure 31)

Every cell has the possibility to store in it self an older version of the specific information. The older version is presented as a small cube inside the bigger one.(Figure 30)

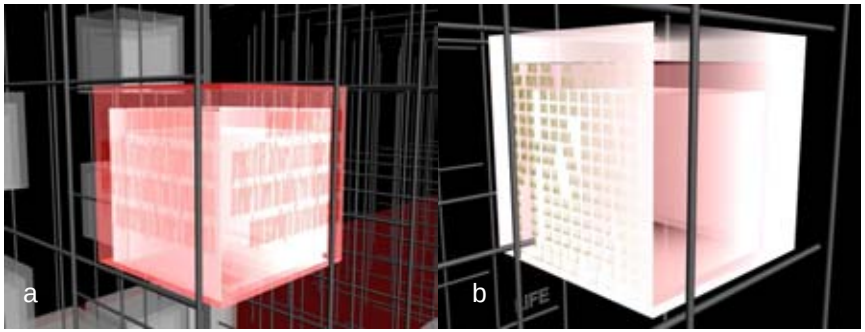


Figure 30 a. b. c. different versions

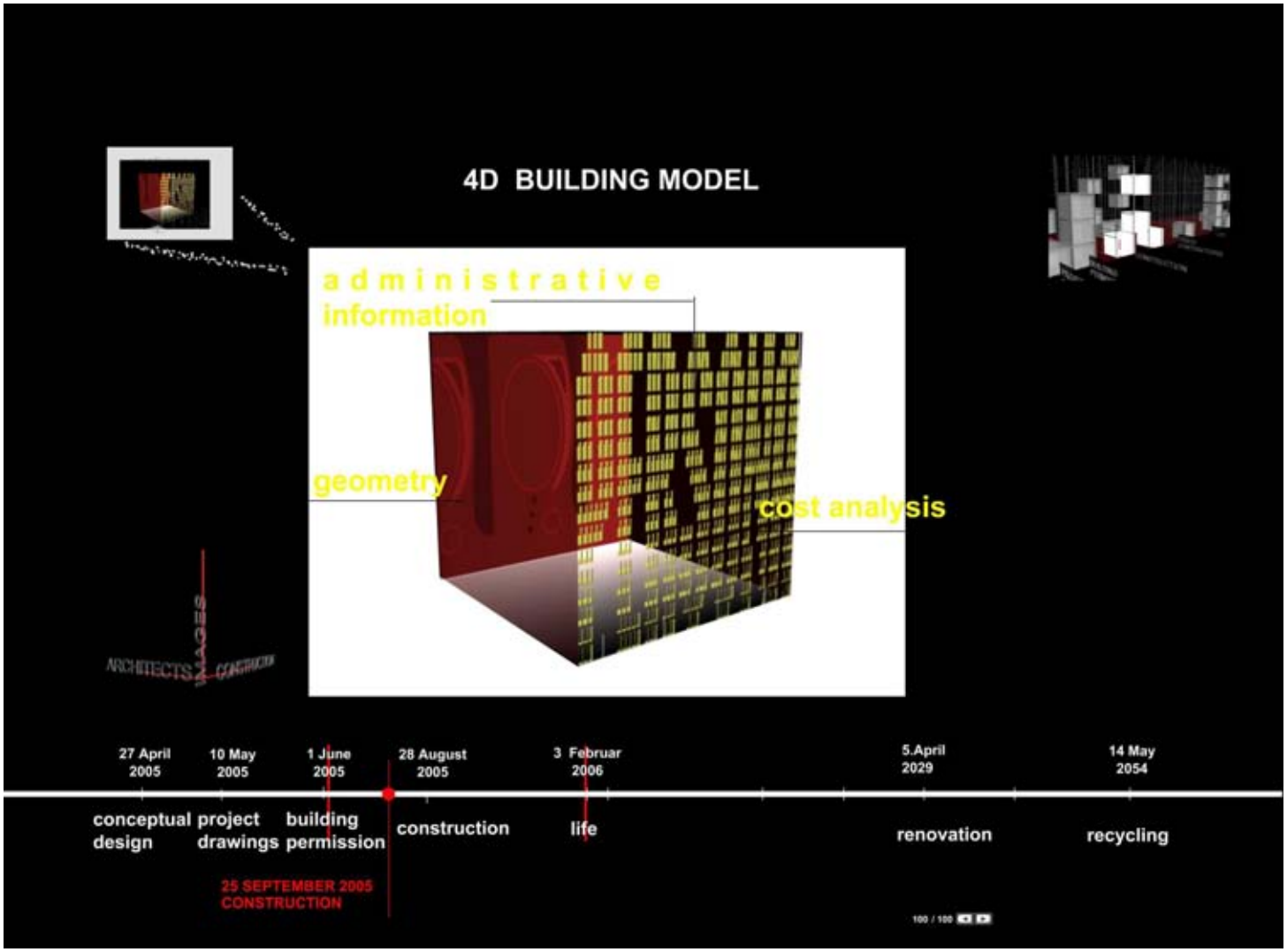


Figure 32, the three data faces

4.2.6 Function of the model

The user defines the time span, for which the design information should be extracted, by moving ant placing the red brackets at the appropriate schedule date on the time line. The cubes that contain the information stored during this period of time are highlighted. (white color).

The user can zoom to the highlighted cells and pick them all or choose one of them. In order to exactly know the position of the cell in the 3D coordinate space, the user clicks on the cube. The color of the selected cube turns to red. On the left side of the window appears the orthogonal axial coordinate system, where in every axis is indicated the label of this position, for example (construction, architecture, plans). Above the coordinate system, a label appears indicating the version and the exact date and status of the information stored in the cube. At the same time, a red button on the time line indicates the exact position of the cube in the time schedule and denotes the date and the status (construction). (Figure 33)

The user click on the cube a second time, then the selection goes to the smaller cube inside, the older version and the appropriate data on the left change. With another more click at the same point the selection goes to the next smaller cube, the oldest version e.t.a. (Figure 34)

The context of the cube can be downloaded and be accessible by the user. After deciding which information someone needs, the user drags the cube to the upper left corner on the small symbol of the wire frame cube and the downloading of the stored information starts.

The actual cube appears offers the three downloaded packages of information, which is geometrical data, cost analysis data and administrative information.
The selection of one of the three categories leads to the next panel of the design object. (Figure 32)

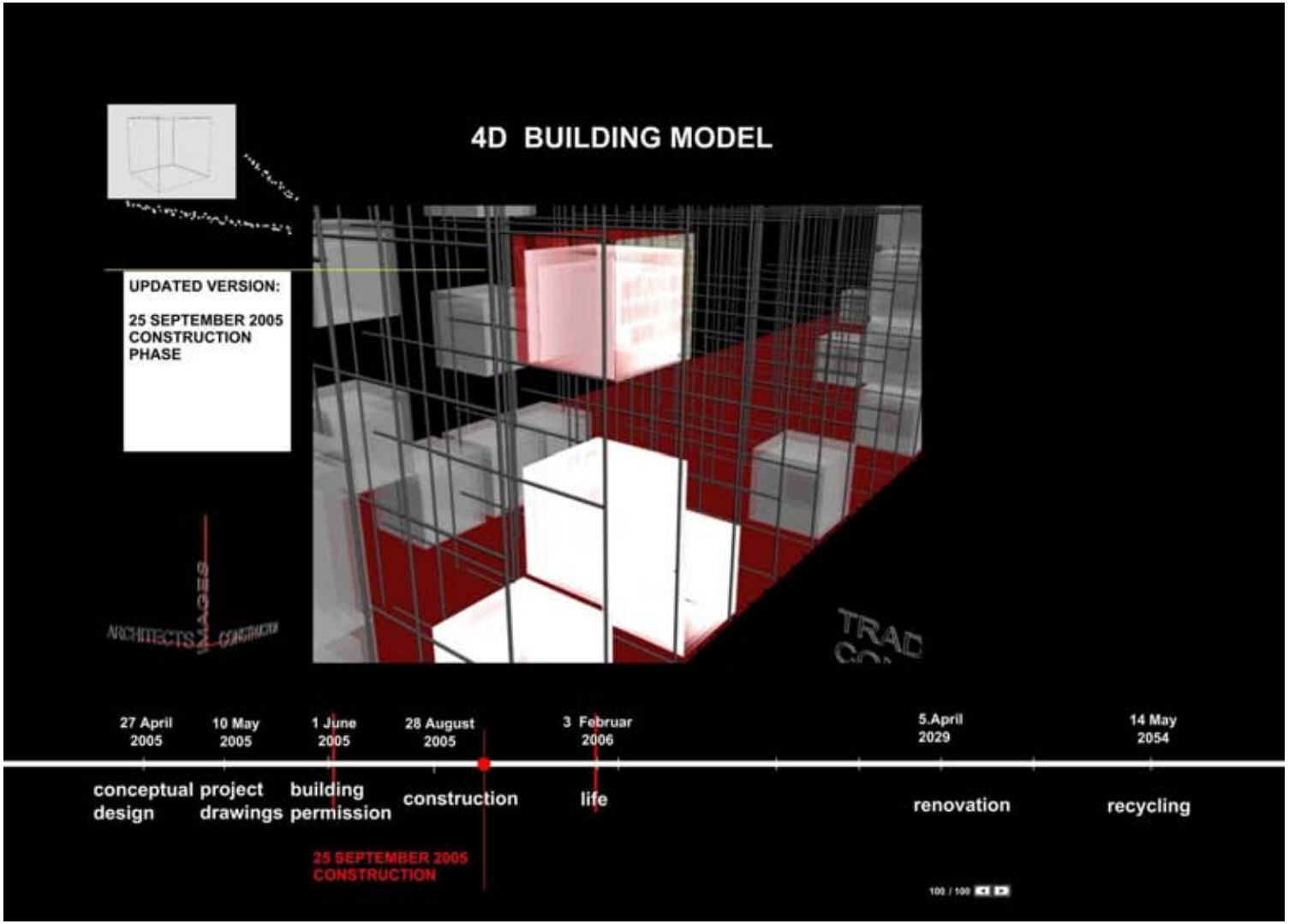


Figure 33, actual updated version

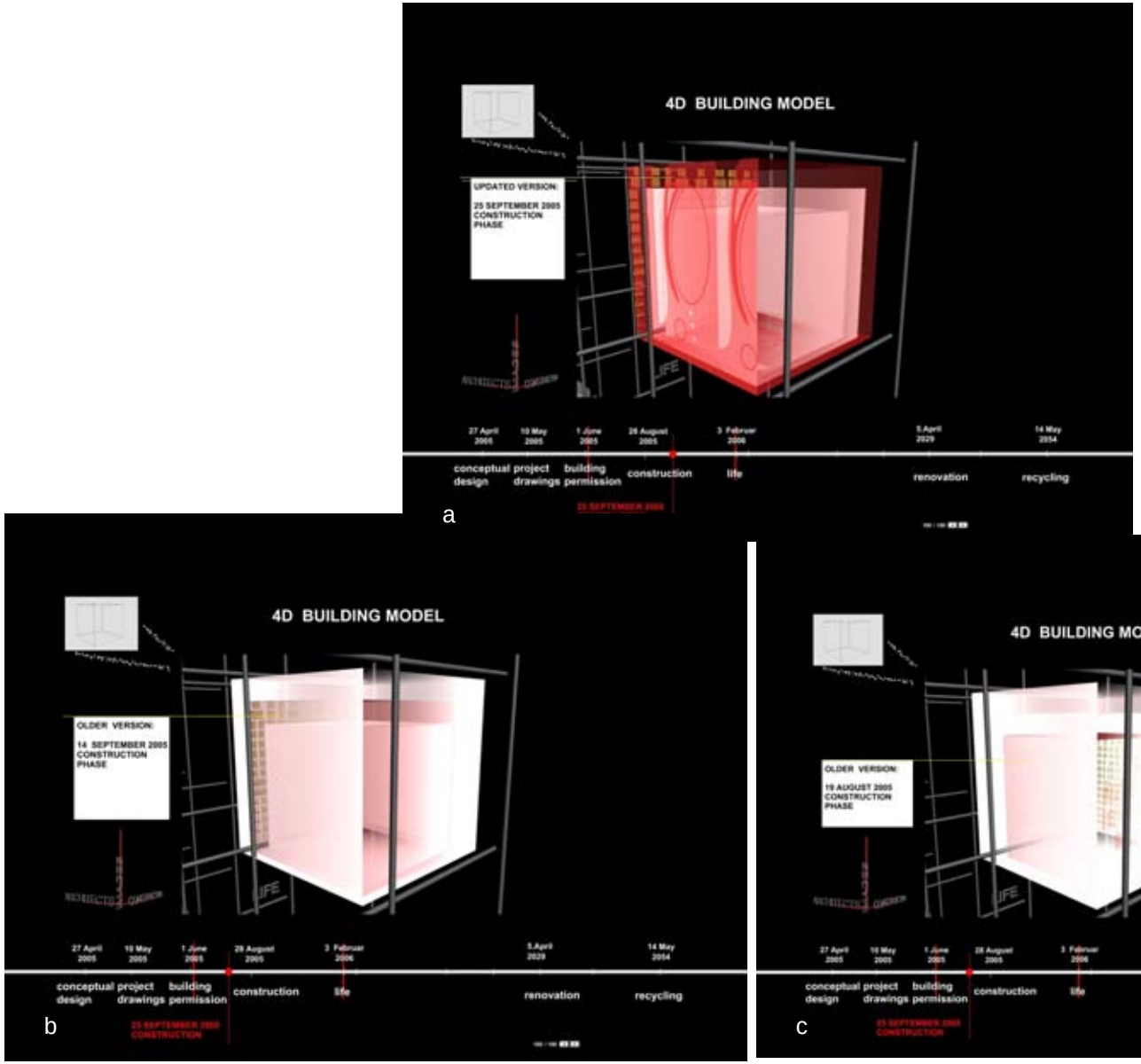


Figure 34 a. b. c, older versions

4.2.7 The menu tab

The menu tab on the top of the page is a tool for the user to change between the two virtual environments, to isolate specific modus and to link to information paths.

Before introducing to the new environment, there is the analysis of the menu tabs above the window necessary. The menu tabs help the user to view quickly the desired information cubes. The main menu consists of the tabs library, time schedule, design participants/components, data types, cube and search. (Figure 35) Each of these tabs consists of sub-menus. Under the tab library the user can find four possibilities: view x-axis, view y-axis, view z-axis, and perspective view, which lead the user direct to the aforementioned views of the library model. The tab time schedule have the following sub menus: design concept, project drawings, building permission, construction, life, restoration, recycling. The user can orient directly to the cubes that store the specific information. The main tab design participants/components have the following sub menus: architects, engineer consultants, project manager, owner, construction firm. The main tab data types consist of the sub menus 3D Model, drawings, images, sketches, notices, contracts. The next tab is the cube. The version A sub menu help the user to isolate all the first design versions of every design status along the time line. The version B all the second versions and the version C all the third versions, e.t.a. Finally the main menu search, when the user wants to find something specific.

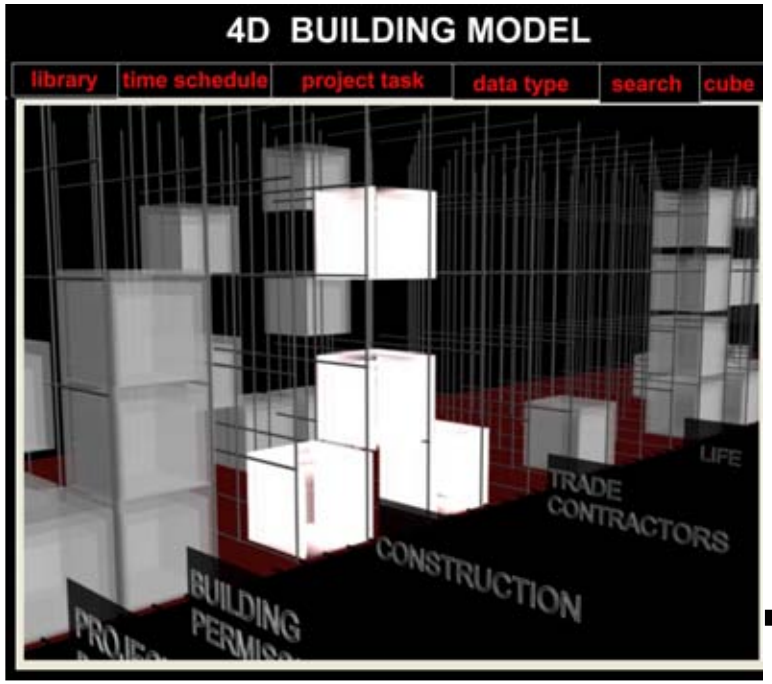


Figure 35, menu tab

4.2.8 Visualization interface of design object

There are three categories of visualized information

Geometrical data
Cost analysis data
Administrative data

There are two kinds of snapshots:

The design object appears as
Single isolated event (Figure 36)
In relation with earlier or later process status. (Figure 37)

The comparison between the different building statuses is achieved with
-Juxtaposition[15]

The changes are highlighted with different colors and transparency factors according to the time passed from the moment when the change occurred.

The past present and future relations are indicated by -the transparency scale

The present, the actual information is indicated by
-the white color
New elements that are added are assigned by
-the yellow color,
Modifications
-the green color
Deleted parts
-the red color [20]

The distinction between design and realized model is indicating by a film strip ordering, where every process status is represented by a frame. The user to compare at any time the impact of specific decisions and the relation between design gestures and realized object.
The project that is used as indicated example is the T-Mobile Center in Vienna. [18]

15 About the visualization of the design process, there is a prototype application developed by Sebastien Riendeau, a PHD student in the University of Montreal called Archichronos. With the use of superimposed models and colored juxtaposed renderings the changes in the design of the building object are visualized. [20]

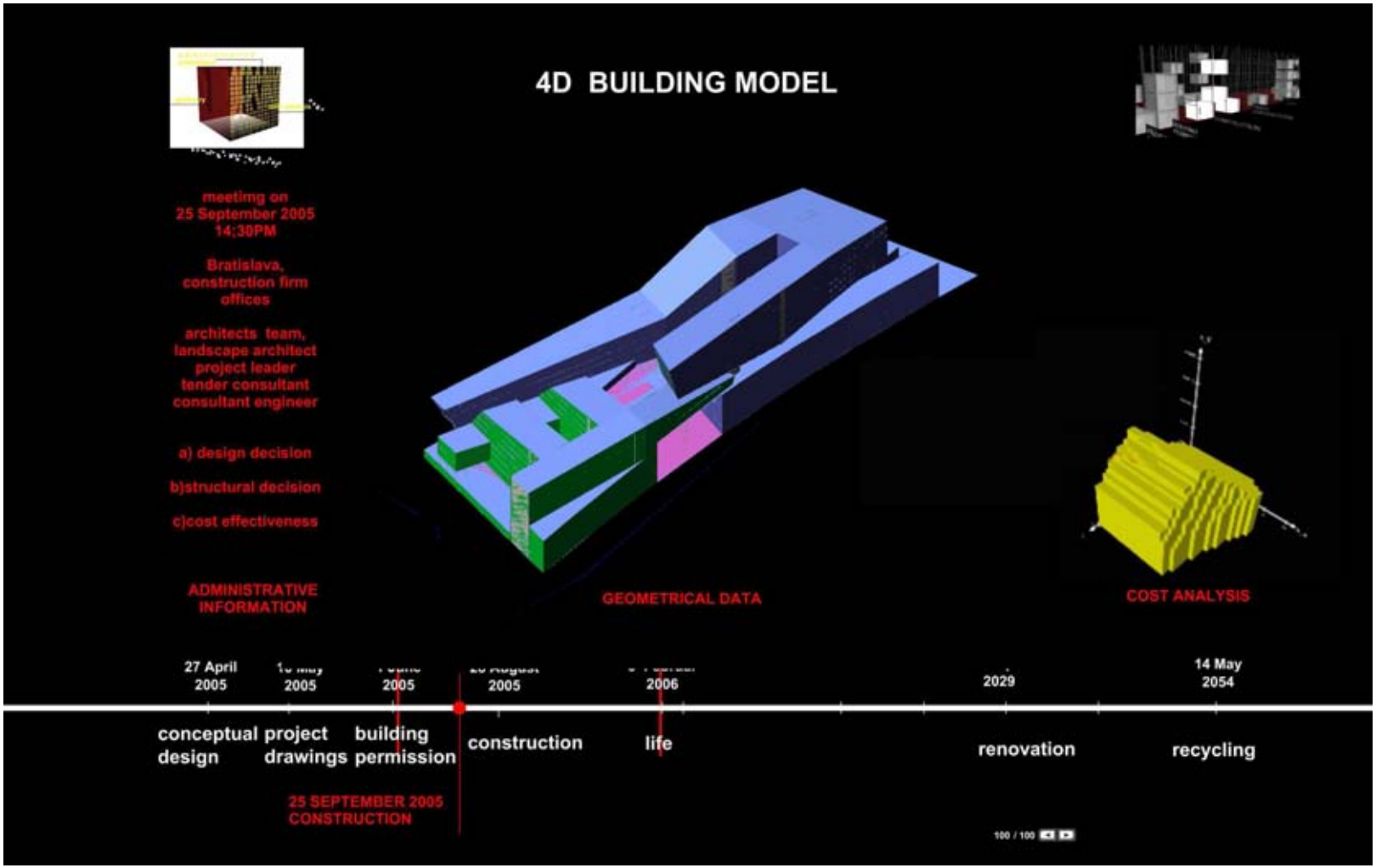


Figure 36, visualization interface of geometrical, administrative and cost analysis data

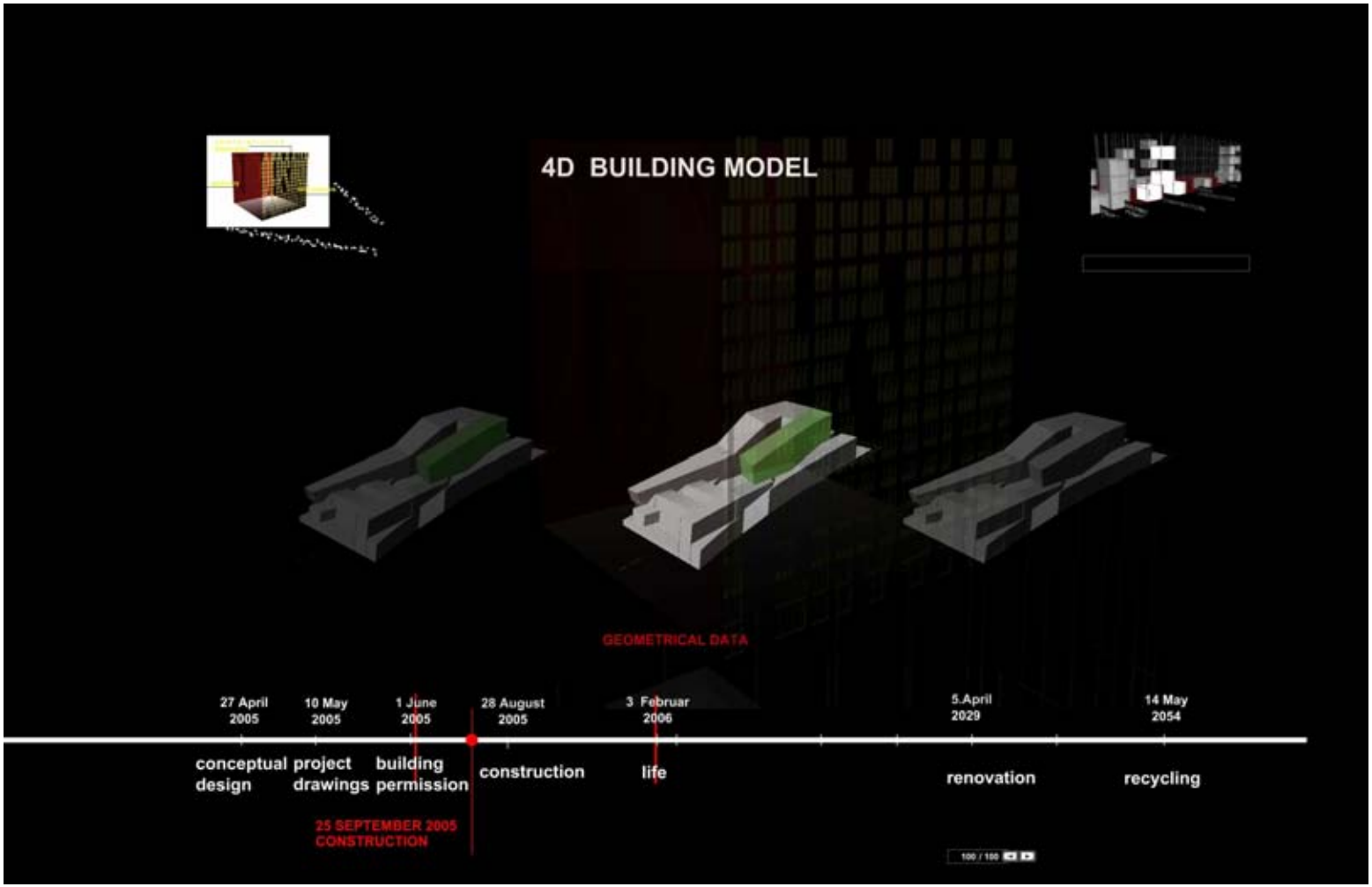


Figure 37, building models between two dates

4.2.8.1 T-Mobile Center[16]

The building named T-Center is both an office building and shopping mall. It is 134,000 square meters large and counts for the largest office building in Austria.

The architectural concept of the building was developed by the architects Domenig-Eisenköck-Peyker.The building is divided both by form and function in four parts: Base Zone, Public Zone, Wings, Fingers. According to the architectural plans, the highest overhanging piece of the building is 'The Lifted Wing'. Right underneath it is the 'Thumb'. This part of the building is also functioning as a landmark for miles around. (Figure 38)

The building materials are reinforced concrete and steel. Two steel trusses support an angled cantilever of 45 meters over 5 stories.

The supporting construction leaves the facade free.

It is interesting to mention that according to the structural planning a new basis had to be created and some parts of the building had to be modified to meet the actual needs.

The model uses the aforementioned building in order to visualize its design and building process, the modifications of the plans and the coordination of different design participants and various components that cooperate in such a complex and large project.

a.

b.

Figure 38 a. b. T- Mobile Center, Source:

[16] T-Center – The Horizontal Skyscraper, V+P Ingenieure ZT

4.2.9 The state of present: Distinction between real object, actual object, virtual object

The definition of the present state aims at to denote its ambiguous essence embodying both past and future elements. The model presents the relation between the actual object, the one being on progress in present time with the real object, the states that happened already and are accomplished and the virtual object, the states planned in future.

4.2.10 Visualization interface of temporal changes of the building object

The successive steps of the building progress are visualized in an *in-between* interface which coordinates the visual library and the single visualization of the object.

The interface consists of three horizontal stripes. In the lower one there are depicted the steps of the building progress already happened. The middle one represents the actual state. The upper own depicts the virtual steps, the ones that are planned during the present state.
(Figure 39-43)

The stripes represent the A Time Series by Mc Taggart. The distinction in two parts aims at visualizing the relation between moments that were present in the future- virtual object-, become actual when the time slice approaches them and exist afterwards as real events in the real object stripe.
The middle stripe aims at detaching the present state from both past and future events, according to Bergson's statement for present perception. It does not belong to the past, it does not belong to the future, it moves between them and the boundaries between them are hard to distinguish.

The red time slice (hyper surface) of the actual state rolls along the time line. Every step of the building progress work stores its relevant data in the appropriate cube cell with its date. As long as the work of this state is accomplished and the plans are published or presented external components the cube cell belongs to the lower stripe of the real object, and belongs to the past.

During the present state future steps are being planned, for example deadlines of presentation of the work progress. This information and the data of the work for this purpose is stored in a cube cell in the virtual object-stripe. When the actual state reaches this moment it compares the actual state with the virtual state, what have been planned for this step. Afterwards, this actual status belongs also to the real object-stripe.

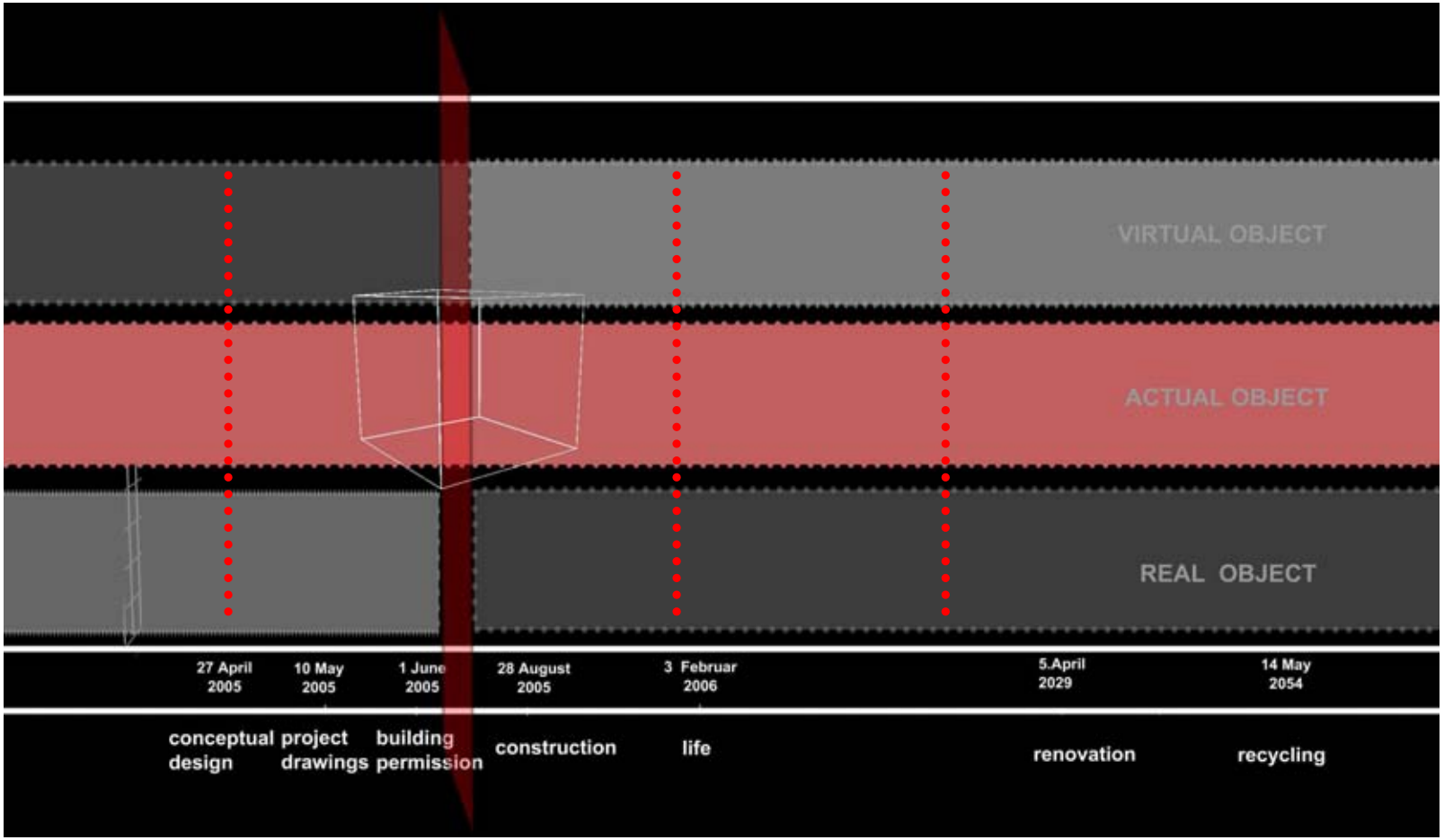


Figure 39, virtual object / actual object / real object

a.

b.

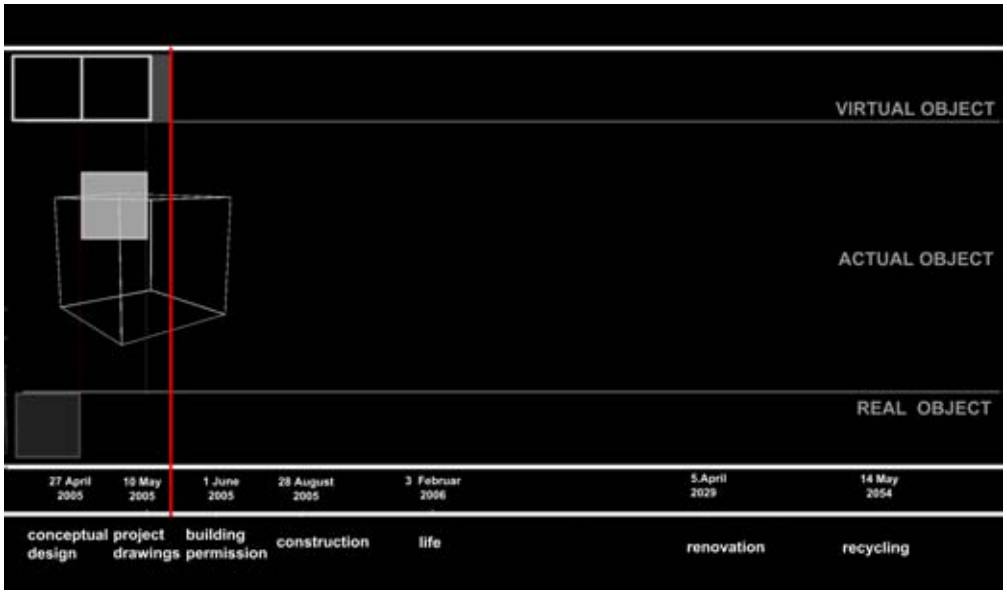
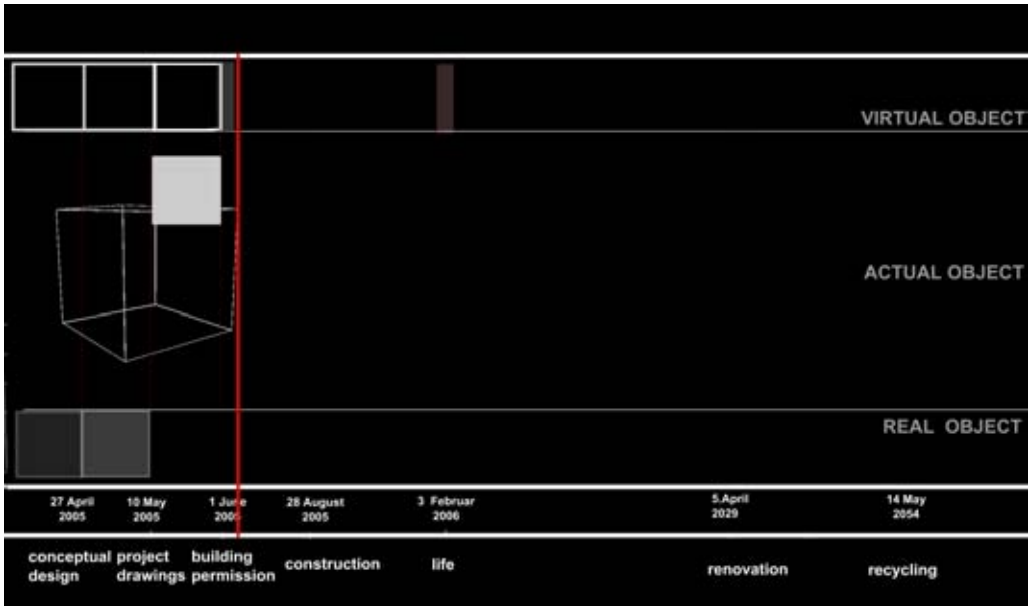


Figure 40, virtual / actual / real

a.



b.

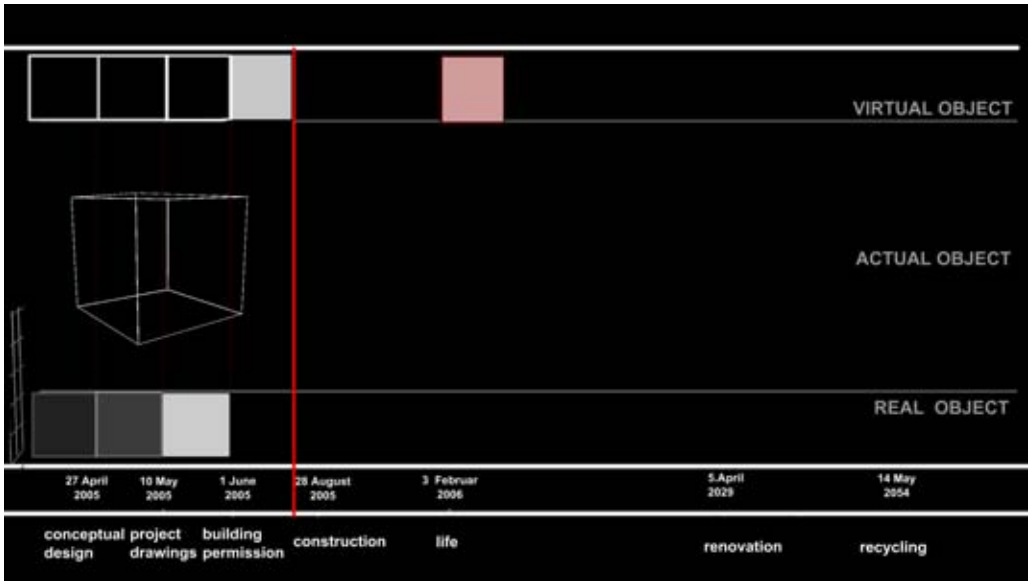
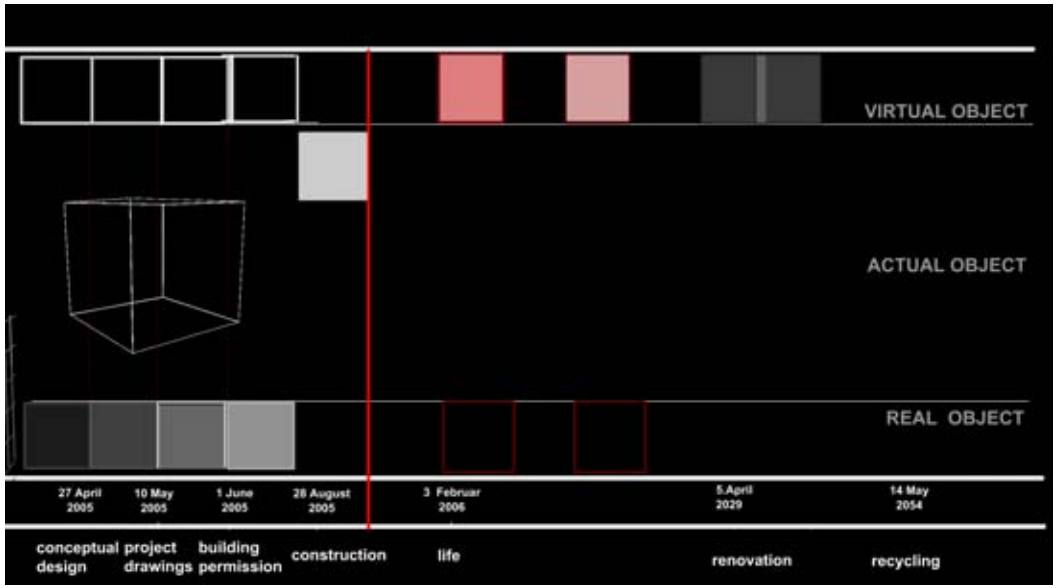


Figure 41, virtual / actual / real

a.



b.

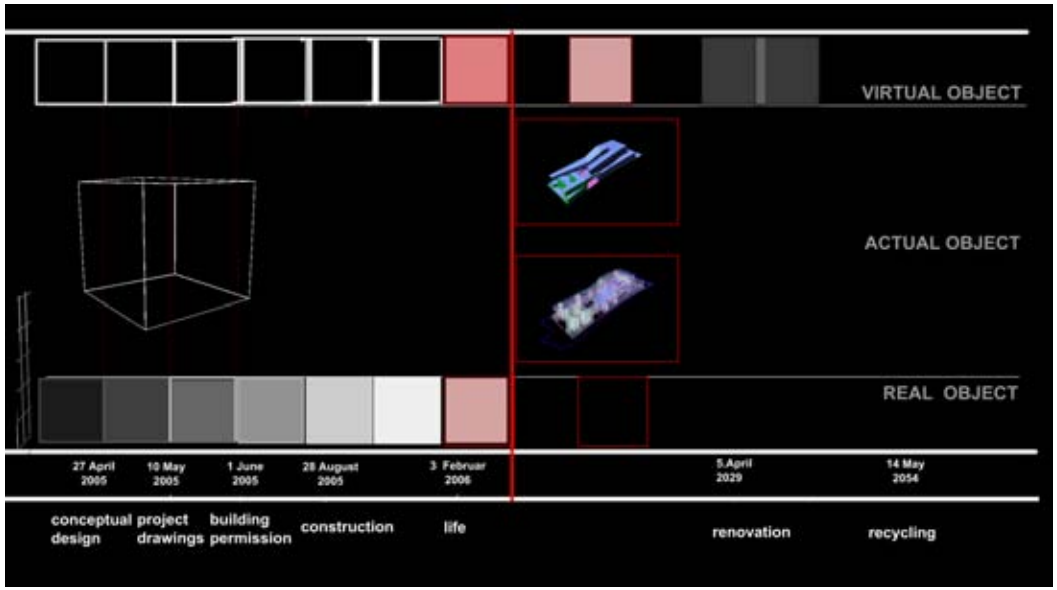


Figure 42, virtual / actual / real

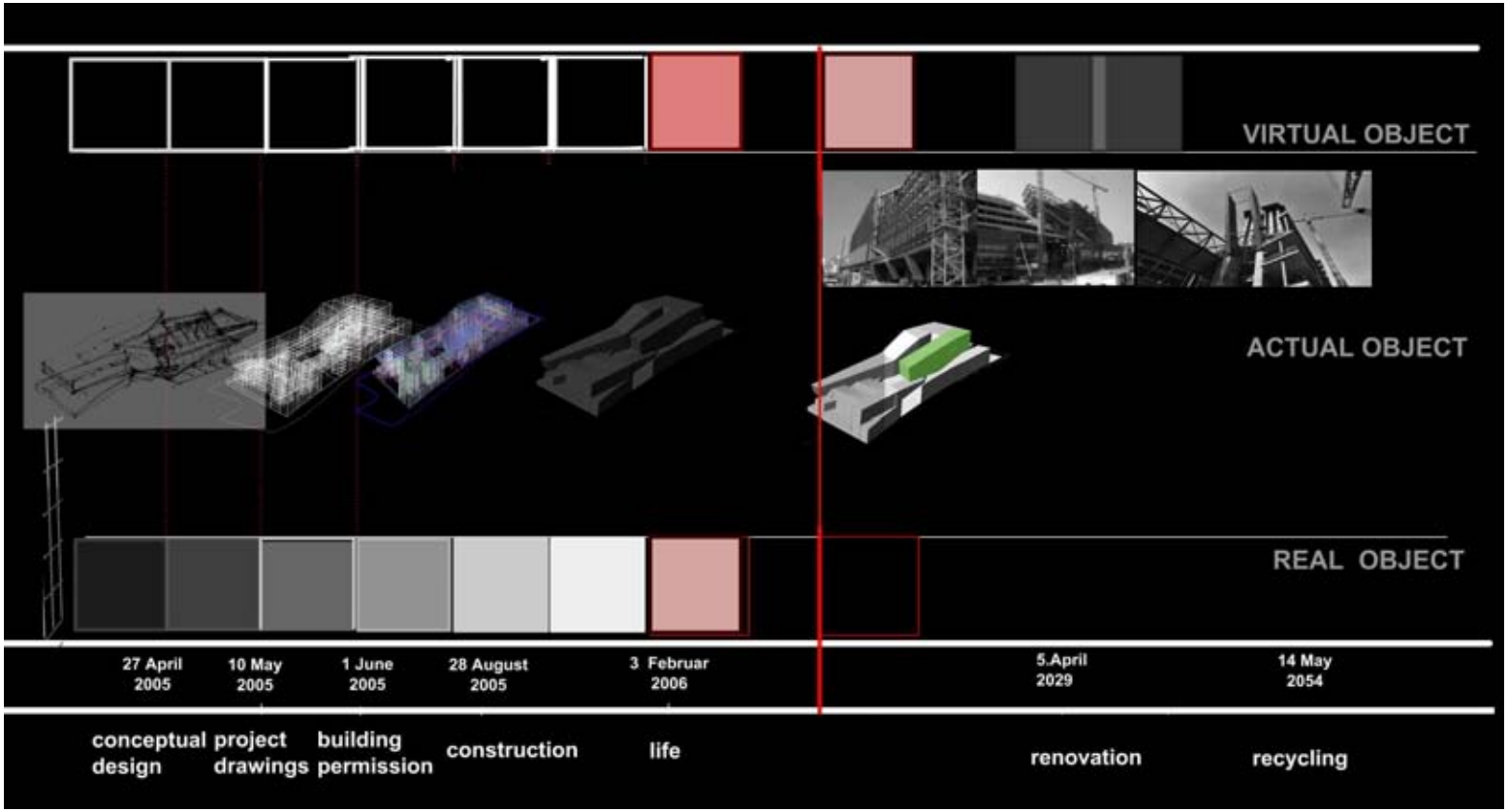

VIRTUAL OBJECT
ACTUAL OBJECT
REAL OBJECT
27 April 2005
10 May 2005
1 June 2005
28 August 2005
3 Februar 2006
5.April 2029
14 May 2054
conceptual design
project drawings
building permission
construction
life
renovation
recycling

Figure 43

5 FUTURE WORK

Through the analysis of a realized building project, it is going to be studied how design steps and decisions are related to the operational behavior of the building, and if certain prognosis about energy efficiency, costs, material life span is accurate. The model is expected to support the design procedure by helping the designer chose among several possibilities, by guiding the designer into the possible building performance that develops under a specific choice.
The serial phases of the design procedure should be reported in terms of plan work, documents, and should be distinguished what kind of information is added in every step, at each time point. What is now in the real time procedure and what is future to understand? (Prognosis, multiple choices). What is their relation?

The construction phase it's the beginning of the realization of design. Parallel actions in construction, multiple cooperation between design, construction components, clients and firms. How is the ontology of the construction procedure going to be described in a time axis table?

The use phase is the interface between human component, environmental factors and materials life spani. Self-monitoring data will be reported in order to estimate the energy consumption, the material use. How can human factor and environmental impacts be reported in the model?

Is this model suitable for any kind of building or are there limitations according to renovation cases or scale (multiple housing, office buildings)?

How can an existing building (for example historical building) be digital stored in the model and supported in its restoration phase, if there are not digital plans or gaps between several phases in plans?

The model should develop further the connection between the different interfaces and how they cooperate with each other.

It is also important to depict the development of each of the three information data, geometry administration, and cost analysis. At the moment it concentrates on the geometrical development and neglects the other two kinds of data.

The model manages to observe the successive steps of the project along the horizontal axis of the time line. It should develop accordingly the ability to approach nearer to a specific status of the process and to go deeper in detailed scale, by zooming and focusing at a specific point of the building. The question would be how the different scales would connect to each other, so that the user can navigate also in the vertical axis of detailed information of the building model.

Another point of issue is the dimensionality of time. The model suggests that there are two dimensions that describe time. Therefore it develops the planar interface with the three series, where virtual object is distinguished from real object.

Finally, it is important to develop a research among the common design software in order to choose the appropriate that could adapt the concept and the function of the 4D Building model.

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LIST OF FIGURES